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MOISTURE-STRENGTH CHARACTERISTICS OF SELECTED SOILS IN THAILAND

VOLUME I: ANALYSES AND APPLICATION OF DATA

by

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August 1967

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to p 47.

DS-2

FOREWORD

The study reported herein was performed by the U. S. Army Engineer Waterways Experiment Station (WES) for the Office, Secretary of Defense (OSD), Advanced Research Projects Agency (ARPA), and is one task of the Mobility Environmental Research Study (MERS) sponsored by OSD/ARPA for which WES is the prime contractor and the U. S. Army Materiel Command (AMC) is the service agent. This study is part of a broad research program to investigate the physical environment as it affects the design and employment of materiel and materiel systems, emphasizing Southeast Asia environments. This study was performed during the period March 1964-June 1966 under the general guidance and supervision of the MERS Branch of the WES, the staff element of WES responsible for the technical management and direction of the MERS program. Funds for data collection and processing were allocated to WES under ARPA Order No. 400. Funds for data analysis and preparation of this report were supplied by the Directorate of Research and Development, AMC, under Task 1-V-0-21701-A-046-02, "Surface Mobility," of Department of the Army Project 1-V-0-21701-A-046, "Trafficability and Mobility Research."

The study was conducted by personnel of the Army Mobility Research Branch (AMRB), Mobility and Environmental (M&E) Division, under the general supervision of Mr. W. J. Turnbull, Technical Assistant for Soils and Environmental Engineering; Mr. W. G. Shockley, Chief of the M&E Division; Mr. S. J. Knight, Assistant Chief, M&E Division; Mr. A. A. Rula, Chief, MERS Branch of M&E Division; Dr. D. R. Freitag, Chief, AMRB; and Mr. E. S. Rush, Chief, Trafficability Section, AMRB. Fieldwork in Thailand was administered by LTC Arthur R. Simpson, Chief, MERS Field Detachment, and conducted by Messrs. A. J. Romano and J. E. Lee,

Trafficability Section. This report was prepared by Messrs. J. G. Kennedy, J. G. Collins, and Miss M. H. Smith.

Acknowledgment is made to the ARPA Research and Development Field Unit in Bangkok, Thailand, for its assistance in administration, facilities, transportation, and operating personnel. The field study required cooperation of many individuals and agencies of Thailand for aid in site location, land use, and data collection, including the following:

Thai Military Research and Development Center
Royal Thai Armed Forces training centers and posts
Meteorological Department
Division of Soil Survey, Department of Land Development
Kasetsart University
Division of Agricultural Research, Department of Agriculture
Department of Irrigation
Department of Rice
Department of Public Welfare
Department of Forestry
Department of Livestock

Special acknowledgment is made to Dr. F. R. Moormann, Soil Specialist of the Food and Agricultural Organization of the United Nations assigned to the Thai Division of Soil Survey, to Prof. Santhad Rojanasoonthon, Soil Scientist, Kasetsart University, and to CPT Prasert Soontharotok and COMDR Duang Bunnag, Thai Meteorology Department, who greatly aided the initiation of the study. Acknowledgment is made also to the Thai engineers and scientists engaged in the study, including Messrs. Chamras Sindhuwong, Phayond Trunshigone, Sanchai Vongthavarravia, Kamol Vitayondom, Chalaj Choeyapunt, Boonkait Sirimontaporn, Jirote Sirimangkala, and Amnuay Kaosingha.

Directors of the WES during the testing program and preparation of this report were COL Alex G. Sutton, Jr., CE, and COL John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

CONTENTS

CONTENTS

Note: Basic Data are presented in Volume II of this report.

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	25.4	millimeters
feet	30.48	centimeters
miles	1.609344	kilometers
pounds per square inch	0.070307	kilograms per square centimeter
pounds per cubic foot	0.0160185	grams per cubic centimeter
Fahrenheit degrees	5/9	Celsius or Kelvin*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use $K = (5/9)(F - 32) + 273.16$.

SUMMARY

Soil moisture, soil strength, and other relevant data were collected in Thailand during two wet seasons and one dry season for use in the development of methods to predict soil trafficability for off-road ground contact vehicles in Southeast Asia. Data were collected at 75 test sites distributed in eight geographic areas which had differences in soils, weather regimes, terrain, and land use.

From data collected monthly at the 75 sites, specific soil strength-moisture relations were derived to depict the changes in strength that corresponded to changes in moisture content. From data collected daily at 17 sites, specific soil moisture prediction relations were derived following procedures developed for sites in the United States. Results showed that the prediction methods were applicable to Thailand sites that were well drained. Modifications in the methods should be developed to account for the influence of water tables when present. Similarities in specific prediction relations between Thailand and the western hemisphere indicated that the development of average prediction relations is feasible.

Descriptions of Thailand and study areas are given in Appendix A. An application of the Thailand data, the derivation of a general soil moisture map for South Vietnam, is given in Appendix B. The basic data are summarized in Volume II.

MOISTURE-STRENGTH CHARACTERISTICS OF SELECTED SOILS IN THAILAND

VOLUME I: ANALYSES AND APPLICATION OF DATA

PART I: INTRODUCTION

Background

1. Soil strength is a major environmental factor governing ground mobility of vehicles; soil moisture content is a major factor governing soil strength. Both the moisture content and strength of a soil are influenced by the nature, properties, and organization of the material as exhibited in profile development, by terrain configuration, and by weather regimes. Vegetation and land use also influence soil moisture content and strength.

2. Soil strength can be determined by direct measurements, but for areas where access is denied, it must be estimated remotely, utilizing knowledge of the area and relations developed from data on analogous environments. General soil classification and aerial-photograph interpretation[1,2] have been studied as methods of remotely estimating soil strength.

3. Since change in strength is principally dependent on change in moisture content, methods for predicting soil moisture content change were studied as a prerequisite to developing methods for forecasting trafficability of a soil, i.e. its ability to support traffic.[3,4] From a value of soil moisture content, trafficability can be estimated.

4. Specific moisture-prediction factors were developed for various test sites in the temperate latitudes of the United States,[4] and from these a set of average relations was derived and tested.[5] Studies were then extended to tropical latitudes in Puerto Rico,[6] the Canal Zone, Hawaii, and Latin America. It was found that the methods used for deriving specific moisture-prediction relations were applicable to these tropical conditions, but that the average values of the relations derived from

temperate sites were not. The first moisture-strength data in the eastern hemisphere were collected in a preliminary study of environmental conditions in Thailand.[7] In a subsequent program in Thailand, moisture-strength conditions were investigated for classification and mapping purposes.

Purpose and Scope

5. The study reported herein investigated changes in moisture-strength conditions with passage of time as a basis for the development of moisture-strength prediction methods applicable to Southeast Asia. Soil moisture and strength measurements and other relevant data were obtained at 75 test sites in eight principal geographic areas in Thailand and represented differences in soils, weather regimes, terrain, and land use. Test data were collected during two wet seasons and one dry season. The basic data are summarized in Volume II, while this volume gives analyses and applications of the data.

Definitions

6. Standard terms used in engineering soil mechanics and soil science, and terms given special meaning in this report are grouped and defined under appropriate headings below.

Standard terms

Soil separate. Mineral particles, less than 2 mm in equivalent diameter, ranging between specified size limits. The names and sizes of separates recognized in the U. S. Department of Agriculture (USDA) Classification System are sand (2.0-0.05 mm), silt (0.05-0.002 mm), and clay (< 0.002 mm).

Soil texture. The relative proportions of the various soil separates in a soil material.

Total pore space. The total amount of voids (air and water) in a unit volume of soil in its natural structure, called porosity in soil mechanics. It is a measure of the volume of water at 100 percent saturation. The total pore space in percent of volume of sample can be computed from the following:

$$\text{Total pore space, \% of sample volume} = \left(1 - \frac{\text{bulk density}}{\text{specific gravity} \times \text{unit wt of water}}\right) \times 100$$

Moisture tension. Moisture tension is considered to be the force, or tension, by which water is held to the soil surface or within interstices; it varies inversely with the soil moisture content. The moisture-tension relation for a particular soil is determined by means of a laboratory device at a sequence of tension or pressure settings. At a given moisture content, the tension is equal to the negative or gage pressure to which free water in the instrument has been subjected in order to be in hydraulic equilibrium, through a permeable wall or membrane, with the water in the soil.

Bulk density. The dry weight of soil per unit volume (grams per cubic centimeter) including voids and interstices between particles. The volume of the soil sample is measured in its field condition, whereas its weight is measured after it has been dried to a constant weight at 105 C (usually 24 hr is required to dry 300-g samples to constant weight). Bulk density is synonymous with unit weight (dry); multiplied by 62.4, it is equal to the dry unit weight in pounds per cubic foot.

Specific gravity. The ratio of the weight of a given volume of solid particles without voids to the weight of an equal volume of water. It is numerically equal to the weight of the solid particles in grams per cubic centimeter. In this report, the solid particles include the organic particles that pass through a 2-mm sieve.

Soil moisture content percent by weight. The soil moisture content expressed as a percentage of the weight of water driven off at 105 C to the weight of the remaining dry soil.

Soil moisture content percent by volume. The soil moisture content expressed as a percentage of the volume of water driven off at 105 C to the volume of the soil in its natural structure including voids and interstices.

Soil moisture content in inches. An expression of moisture content by volume of soil in its natural structure in units of depth per unit depth (e.g. inches of water per inch of soil). The usual expression in this report is inches of water per 6-in.* soil layer. These moisture contents are computed as follows:

$$\text{Moisture content, in. of water per 6-in. soil layer} = \frac{\text{moisture content, \% by wt,} \times \text{bulk density} \times 6}{\text{unit wt of water (1)} \times 100}$$

$$\text{Moisture content, in. of water per 6-in. soil layer} = \frac{\text{moisture content, \% by wt,} \times \text{dry unit wt} \times 6}{\text{unit wt of water (62.4)} \times 100}$$

Wilting point. The soil moisture content at which soil cannot supply water at a sufficient rate to maintain turgor in the plant tissue, and the plant permanently wilts. The 15-atm soil moisture tension value approximates the wilting point.

Water table. The upper surface of groundwater; locus of points in soil water at which the hydraulic pressure is equal to atmosphere pressure.

Water table, perched. The upper surface of a body of free groundwater in a zone of saturation, separated by unsaturated material from an underlying body of groundwater in a different zone of saturation.

Soil-moisture prediction terms

Specific moisture-prediction relations. Relations derived from and applied in the prediction method to a specific site. Prediction relations include accretion and depletion curves, field-maximum and field-minimum moisture contents, transition dates, and minimum-size storms.

Available storage. The difference between the amount of water in a soil layer at the field-maximum moisture content and the amount of water in the layer at any given time. Available storage is expressed on a volume basis (in. per 6-in. soil layer in this report).

Field-maximum moisture content. The recurring maximum moisture content of a soil layer in its natural position. This value, the highest point on the depletion curve, represents maximum wetting during the wet

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* A table of factors for converting British units of measurement to metric units is presented on page ix.

season of the period of daily record, usually one year.

Field-minimum moisture content. The lowest value of each depletion curve, representing the lowest average moisture level that occurs during the dry season of the period of record, usually one year.

Wetness index (WI). A numerical index expressing the effect of environmental conditions on the maximum moisture content in the surface-to-12-in. layer of soil. The degree of wetting is determined by the depth to a perched or permanent water table, and the depth of penetration of water from precipitation.

Minimum-size storm. The smallest storm used in moisture prediction for a particular soil-vegetation condition. Smaller storms do not appreciably wet the soil and depletion occurs.

Accretion. Moisture gain within a soil layer. The moisture gain is caused primarily by precipitation. Lateral flow and a rise in water table may directly contribute to accretion at some sites; however, these sources are usually related to precipitation.

Accretion classes. Accretion is divided into two classes, I and II, depending on whether rainfall is less or more, respectively, than the available storage in the surface-to-12-in. layer of soil.

Accretion regression. A linear regression computed for each 6-in. soil layer and accretion class, by which accretion is related either to rainfall (for class I) or available storage (for class II).

Depletion. Moisture loss from a given soil layer for a period of no accretion. The moisture loss is caused by evapotranspiration and drainage.

Transition date. A date at which the average depletion rate exhibits a distinct change as shown in the plot of the daily soil moisture record.

Average moisture-prediction relations. Relations obtained by averaging the data from a large number of soil-environmental conditions and applying them in the prediction method.

Site terms

Prediction development sites (PD sites). Sites on which detailed measurements were taken daily, and from which specific accretion and depletion relations were derived.

Survey sites (TS sites). Sites established for periodic collection of data to derive soil strength-moisture relations, and to verify the applicability of average moisture-prediction relations. Monthly measurements generally were made.

Strength terms

Critical layer. The layer of soil regarded as most pertinent to establishing relations between soil strength and vehicle performance. In fine-grained soils and sands with fines, poorly drained, it is usually the 6- to 12-in. layer. However, the critical layer may vary with weight of vehicle and with soil strength profile.

Cone index (CI). An index of the shearing resistance of a soil layer obtained with the cone penetrometer. The value is used as a dimensionless number, but is actually pounds of force on the handle divided by area of the cone base in square inches.

Remolding index (RI). A ratio expressing the proportion of original soil strength that will remain under the traffic of a vehicle. The ratio is determined from cone penetrometer measurements made before and after remolding a soil sample using a special instrument and procedures.

Rating cone index (RCI). The product of the measured cone index and the remolding index for the same layer of soil.

Shear stress, peak. The greatest shear stress recorded by the sheargraph (a hand-operated field instrument) when sheargraph head causes initial soil failure for a particular normal stress maintained on the handle.

Shear stress, ultimate. The greatest shear stress recorded during the continued rotation of the sheargraph head after initial soil failure for a particular normal stress maintained on the handle.

PART II: TEST SITES

Site Selection

7. Seven primary areas, plus the area around Bangkok, were selected for study. Each area was identified by the major town therein as follows: Chiang Mai, Khon Kaen, Nakhon Sawan, Lop Buri, Pran Buri, Chanthaburi, and Hat Yai. These areas were representative of the major soil, terrain, vegetation, and weather conditions throughout Thailand. A general description of Thailand and the study areas is given in Appendix A.

8. Site selection was based primarily on pedological identification of the soil, including the great soil group and soil series, made by soil specialists.* Uniformity of soil, ground configuration, and vegetation within and about each sampling area were considered also. Sites included (a) the soils dominant in Thailand, (b) soils not necessarily extensive in Thailand, but dominant elsewhere in Southeast Asia, and (c) some soils of limited areal extent but expected to be critical for trafficability periodically. Some sites with mixed pedological characteristics, such as overwashed phases, were selected because they presented a greater potential trafficability problem than nearby distinct pedological types. In addition, United States and Thai Army personnel in each area indicated locations of problem soils encountered in military exercises, and sites were selected on similar soils where possible.

9. From seven to thirteen sites were located in each study area outside the Bangkok area (plate 1). The number was governed by the logistics and work load of two sampling crews rather than by the total array of soil-site conditions; however, a fair representation of soil and site conditions was obtained.

Site Descriptions

10. Descriptions of each site including topography, drainage, vegetation, land use, and soil properties are summarized in tables 1 and 2.

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* Dr. F. R. Moormann and Prof. Santhad Rojanasoonthon with assistance from Messrs. Samarn Panichapont, Vira Poomvises, and Tanit Thongchutas who had completed soil surveys in various areas.

Climate and weather conditions are given in Appendix A. The relative positions and the soil parent materials of the test sites are shown by schematic transections across each study area in plates 2 through 4. Other pertinent information not given in the tables but useful for interpretation of results follows.

Chiang Mai area (plate 2a)

11. Survey site TS 1 was located on a sandy natural levee of the Ping River, and TS 2, in fine sediments behind the levee. TS 3, on the ridge of a sloping spur in the mountains about 2500 ft above the valley floor, had a relatively deep soil, derived primarily from micaceous gneiss, with appreciable rock fragments at the 36-in. depth. This was the only mountain soil tested in the study. TS 4 was located in a depression of the alluvial floodplain and had a black soil. TS 5 was beside an intermittent stream on the floor of a gully in the high terrace and was presumably the wettest location in this well-drained, upland formation. TS 6 was located in the lower terrace, in outwash material from the high terrace and was diked for rice cultivation. TS 7 was on the narrow floodplain of a stream emerging from the mountains. Prediction development sites PD 241 and PD 243 were located on old rice lands, now lawns, with different water table regimes; PD 242 was on the middle terrace on a coarse, well-drained soil covered with an open forest of broad-leaved dipterocarp trees. TS 19B, C, and E were on low terraces and colluvial-alluvial outwashes from sandstone-shale hills, and each site differed in soils and drainage. One, TS 19C, contained soil classed in the Unified Soil Classification System (USCS) as SC, sand with fines, poorly drained, which is often a problem soil for trafficability.

Khon Kaen area (plate 2b)

12. TS 12 was located on the cutting side, TS 13 on the natural levee of the deposition side, and TS 14 in the clayey slack-water deposit area near the Lam Chi River. TS 56A, B, and D were located on medium-textured soils on the lower part of the low terrace near the Nong Loeng Puai floodplain, whereas PD 247, 248, and 249 were on coarse-textured soils at higher elevations of the low terrace. PD 247 was in a depression of dark-colored soil. The subsoil of PD 249 had a columnar structure,

evidence of high sodium content commonly found in solodized Solonetz soil usually found in subhumid to semiarid regions. PD 246 was in the upper middle terrace. TS 11 was in an outwash of a broad drainageway from the high terrace onto the low terrace. This soil had a high salt content, as evidenced by surface crusts and sparse vegetation. TS 9 was located in a colluvial-alluvial apron outwash of high terrace materials covering the low terrace; TS 10 was in the high terrace material.

Nakhon Sawan area (plate 2c)

13. TS 16 was located in the floodplain of the Ping River in a clay soil. TS 15, 18, and 19 were on the low terrace, and each site differed in age and soil texture from the others. TS 17 was also on the low terrace but had an accumulation of organic matter. PD 251 was located on a peneplain plateau of limestone and old terrace materials. TS 20 was on an outwash apron near a steep limestone hill.

Lop Buri area (plate 3a)

14. TS 26 was located on the Chao Phraya floodplain on an acid-sulfate clay derived from marine sediments; TS 25, 25A, and 25B, although similarly located on the low terrace adjacent to hills of andesite, differed in soil texture and drainage. TS 24 was on colluvial outwash from andesite, and TS 21, 22, and 23 were on a transection of clayey material derived from limestone and old alluvium. TS 21 was a Grumusol, TS 22 was on a soil that had some limestone concretions and some mixing of local alluvium, and TS 23 was on recent alluvium from nearby Yai Creek. PD 252, 253, 254, and 256 were located on plateaus derived from limestone with some shale. Each of these sites differed in topographic position and drainage. PD 252 was in a depression near a stream where the soil had high organic matter content and marl concretions to a depth of 4 ft. Limestone was exposed at the ground surface in spots surrounding PD 256. PD 255 was located in the lower floodplain of a tributary of the Pa Sak River. Ruts where vehicles had been immobilized previously were noted at TS 23 and PD 255.

Bangkok area (plate 3b)

15. The soil at PD 244 was developed from uplifted marine sediments and brackish alluvium; that at PD 245 from more recent river alluvium with

somewhat brackish marine sediments. At TS 8, the area was a recently man-made system of parallel ridges and borrow-pit ditches for intensive local fruit and vegetable production. These three sites, plus TS 26 of the Lop Buri area, represent the majority of soils found in the lower Chao Phraya plain.

Pran Buri area (plate 3c)

16. PD 257 was located in the wash-over apron of the back beach; the soil was sand with fines. TS 29 was on semirecent to old marine sediments with a high salt content. TS 30 was on an old marine terrace with an admixture of colluvium from adjacent gneiss hills. TS 31 and 32, on a low marine terrace, differed in internal drainage (TS 31 was poor and TS 32, good). TS 33 had mixed semirecent river alluvium and colluvium from the low marine terrace; TS 34 was on a semirecent river terrace with alluvial sediments washed from quartzite-phyllite mountains.

Chanthaburi area (plate 4a)

17. TS 36 was located on the shale hills north of Sattahip and TS 35 was nearby, on coarser textured materials of an old marine terrace. TS 37 was also on the old marine terrace, but the soil had more clay than TS 35. TS 38 was in a depression behind an old beach ridge and probably had been a marsh or shallow lagoon with rush vegetation. The soil was high in organic content and contained considerable amounts of amorphous silica identified as plant opal with possibly some diatoms.* (This soil type is more common in northern Europe where it is named gyttja.) TS 39 was on recent river alluvium over terrace material, TS 40 on a low alluvial terrace of fine-textured material with concretions developing into hard plinthite (laterite). PD 258 was located in shale hills but the soil had a finer texture than TS 36 soil, which was also developed from shale. PD 259 was the only site in this study located on soil derived from basalt. This soil had typical properties of such soils, i.e., a friable consistency with a porous, fine ped structure and high iron oxide content, as indicated by its specific gravity of 2.9. Few

* Identification was made by Mr. A. D. Buck, Research Geologist, Concrete Division, U. S. Army Engineer Waterways Experiment Station.

areas of this soil occur in Thailand, but it is common elsewhere in Southeast Asia. TS 41 soil was slightly coarser and less plastic than that of TS 37, and was probably mixed marine terrace material with colluvium from granite. TS 42 was located on the colluvial fan at the base of a high granite mountain.

Hat Yai area (plate 4b)

18. TS 50 was located in a depression in wash-over material of the back-beach apron and was composed of sandy soil with an accumulation of organic matter. TS 49 was located adjacent to a saltwater lagoon on acid-sulfate marine clay, which was high in organic content and supported sparse, shrubby mangroves and grass. TS 48 was on a low terrace of marine sediments. PD 260 was on a higher terrace composed of old freshwater alluvium. TS 46 was in a broad gully filled with recent, local alluvium. TS 47 was located on colluvium outwash from hills of shale and metamorphic rock, TS 45 was near the base of a colluvial slope of a sandstone mountain, TS 44 was on gravelly colluvium at the lower slope of sandstone-shale hills, and TS 43 was on semirecent river alluvium in the high terrace near Rattaphum Creek.

Detailed information not reported

19. Because of time and money limitations, a complete analysis was not made of all the detailed information collected in this study. However, it is on file at the U. S. Army Engineer Waterways Experiment Station (WES) and includes the following:

a. Soil profile descriptions of each site.

b. Topographic maps with 6-in. contour intervals extending from 10 to 100 ft around each site.

c. Terrain transections through each site area extending ±50 ft from the center of the site.

d. Photographs.

e. Vegetation identification on the site and in the area.

f. Surface-water data.

Layout of Sites

20. Each site was laid out in a rectangle 21 by 36 ft (see fig. 1), marked off by permanent corner posts. This rectangle was divided into three blocks, 12 by 21 ft, and subdivided into 3-ft sampling squares.

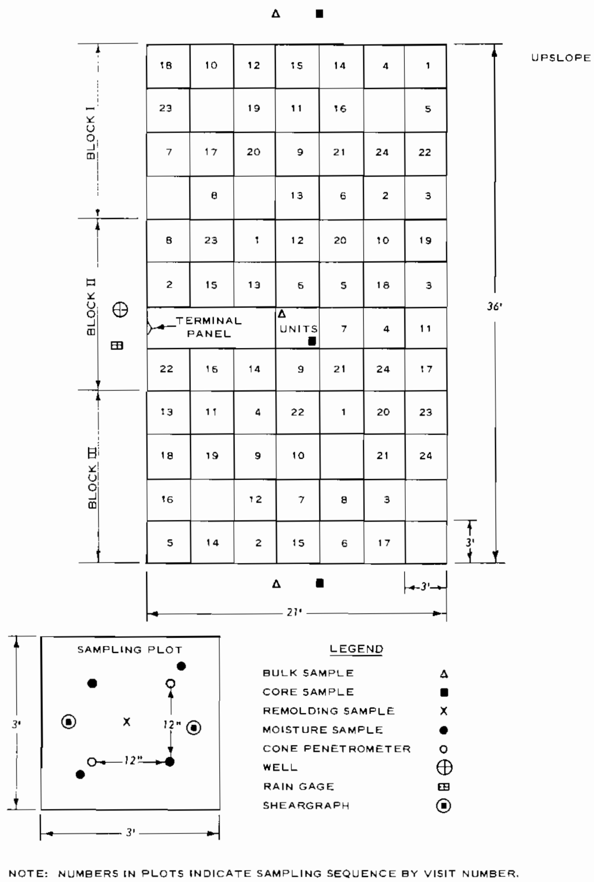

Fig. 1. Site layout

The squares were numbered at random from 1 to 24; four were not numbered. A given number, starting with 1 on the first visit, was sampled from each block on a particular visit. The same set of numbers was used at all sites.

21. On sloping terrain, the length of each site was oriented upslope with block I at the top. On flat terrain, the site was oriented to terrain or cultural features such as ridges, fences, etc. A fence was installed about 5 ft beyond sampling boundaries to deter disturbance of the test site.

PART III: TEST PROCEDURES

22. Periodic field tests for dynamic factors (those changing with time) were conducted on two schedules: Data on soil moisture and related factors used for deriving soil moisture-prediction relations were collected daily at 17 PD sites. (Daily records were not obtained for two of the 19 PD sites because of instrument malfunction.) Data on soil strength, soil moisture, and other factors used in strength analysis and in testing soil moisture predictions were collected at 1-month intervals at all 75 sites. Tests for static factors (those not changing with time) used for describing the site were made once at all sites. Testing began in May 1964 and was completed in November 1965.

Daily Measurements

23. Measurements were taken early each morning at the 17 PD sites to give a consistent 24-hr time interval. Included in the measurements were soil moisture and temperature, rainfall amounts, depth to groundwater, depth of surface water, air temperature, surface conditions of ground, and notes on site condition. These data are given in Volume II, table II-2.

Soil moisture and soil temperature measurements

24. Electrical resistance units[8] were installed at PD sites only. Each unit consists of two Monel metal screen electrodes separated and surrounded by layers of fiber-glass cloth in a perforated Monel metal case for measuring soil moisture, and a thermistor for measuring temperature. The unit is 1 by 1-1/2 in. and 1/8 in. thick. A cable of unit wires, buried 3 in. underground, led from the installation hole to a plastic terminal panel mounted on a post. This panel had three bolt-terminals per unit (moisture, temperature, and ground) for attaching clamps from the meter. A hole was prepared at the center of the site using a 4-in.-diam auger. Units were installed in 3-in. vertical increments at depths from 1-1/2 to 16-1/2 in. by pressing them in a vertical plane into the wall of the hole,

and in a spiral pattern so that no unit was directly below another to assure minimum disturbance of moisture flow to and past the unit (fig. 2). Soil was then replaced in the hole and repacked to its original volume by layers. Small surface depressions were avoided in locating the spot for installation and the refilled hole was mounded slightly to prevent funnel action of surface water.*

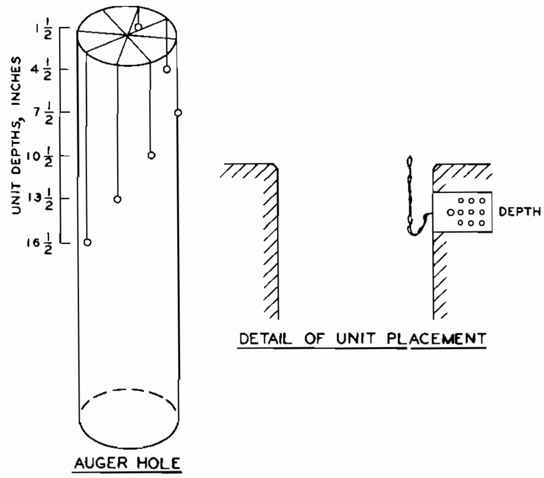

Fig. 2. Installation of moisture units in auger hole

25. Electrical resistance of the moisture and temperature determining units was measured with a battery-operated a-c meter. The daily moisture unit readings were processed in a combined computer operation that included correction of thermistor readings, conversion to temperature, correction of moisture readings to a common temperature of 60 F, and conversion of these values to moisture content in inches per 3-in. soil layer.[8,10] The final conversion was made by 3-in. layers using calibration curves drawn through the data points for the corrected unit readings plotted versus monthly gravimetric moisture values. An example of a calibration curve is shown in fig. 3. The double scale of moisture contents converts percent weight to inches of water calculated from the bulk density of 3-in. layers. Values by 3-in. layers were averaged by 6-in. layers for analysis with strength data.

Rainfall

26. Standard 8-in.-diam rain gages maintained by the Thai government were used at sites located within 100 ft. At the remaining sites, rain gages 5 in. in diameter and 9 in. deep, made of galvanized sheet metal, were mounted on a stand 3 ft above the ground. At sites with trees,

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* The installation and calibration procedures were developed for trafficability purposes to obtain measurements in surface layers of natural soil with minimum disturbances. It should be noted that these differ from procedures prescribed and commonly used in general agronomic studies.[9]

the gages were installed in nearby clearings, with the distance to the nearest tree equal to or exceeding the height of the tree. All rainfall measurements were recorded to the nearest hundredth of an inch.

Groundwater

27. Groundwater wells 4 ft deep were installed at all sites. Holes were dug with a 4-in.-diam auger and cased with 3-in.-diam galvanized sheet metal pipe, cut to a length 1 ft longer than the depth of the hole. The lower half was perforated with 1/4-in. holes spaced at 2-in. centers, and the top was capped with a can. The annular space was packed with pea gravel to 1 ft from the surface, and the remaining foot with silt or other low permeability, nonshrinking soil to seal against leakage. The well was installed on a high spot to avoid puddles, and the soil was mounded around the pipe to form a watershed. At 15 sites, where soil layers of low permeability were suspected at depths less than 4 ft, a second well was installed from the surface to the top of the low permeability layer, with the lower half of the pipe perforated and gravel packed, and the upper half sealed against leakage. Depth to groundwater was measured to the nearest half inch.

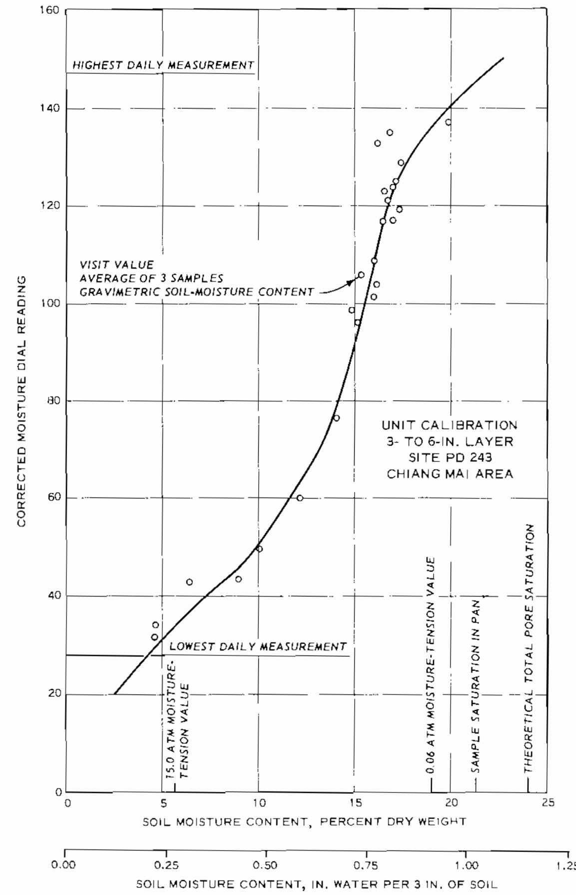

Fig. 3. Soil moisture unit calibration curve

Surface water

28. Surface water, when present, was measured to the nearest half inch by a staff gage made from a ruled board 1 by 2 in. and about 4 ft high, with inch and foot markings that could be read at a distance. The gage was mounted vertically on a post at each site suspected of having impounded water, such as diked rice fields, or in ditches or streams near

sites possibly subject to influence of surface water.

Air temperature

29. A maximum-minimum thermometer for air temperature determination was mounted on the terminal post (fig. 1) and oriented in a northerly direction; sideboards were installed on the post to block direct sunlight from the thermometer. Temperature at the time of the visit was recorded, as well as the maximum and minimum temperatures for the previous 24 hr.

Ground-surface condition

30. Surface condition of the soil was recorded as inundated, having scattered puddles, saturated, moist, dry-friable, dry-hard, or dry-cracked. Anything that could have affected measurements also was noted.

Monthly Measurements

31. Monthly measurements of moisture content (MC), cone index (CI), remolding index (RI), and surface shear strength, and other factors normally measured in daily visits to PD sites were made at all sites. On these visits, one square from each of the three blocks of a site was tested (fig. 1). These data are listed in Volume II, table II-1. Gravimetric moisture samples were used to calibrate electrical resistance units at PD sites.

Moisture content (MC)

32. Samplings for gravimetric determination of MC were taken at 3-in. vertical increments from the surface to a depth of 18 in. Usually, for a given 3-in. layer in each sampling square, four borings were taken with an open-side tube sampler (Oakfield type) and sealed in a can. When free water was present on the surface or in the soil, two 3-in. borings were made in each layer of a square using a trafficability sampler that can retain free water better than the Oakfield sampler. Moisture contents were calculated from weights before and after oven-drying at 105 C for 48 hr. The three sampling square values were averaged for each layer to give an average site value for calibration of units by 3-in. layers. The layers were averaged by 6 in. for correlation with strength, table II-1.

Cone index (CI)

33. CI was measured with a cone penetrometer at 3-in. vertical increments from the surface to 18 in. at two locations in a square of each block at a site. For firm soils, the 0.2-in. cone with 750 dial gage capacity was used; for soft soils, the 0.5-in. cone with 300 dial gage capacity was used. Details of the CI and other soil strength tests are given in reference 11. Average CI values were computed for the 0- to 6-in., 6- to 12-in., and 12- to 18-in. depths.

Remolding index (RI)

34. To determine RI, remolding tests were conducted on cores taken from the 6- to 12-in. layer of three sampling squares at a site when soil conditions permitted sampling. Cores were taken with the trafficability sampler and transferred to the remolding cylinder; CI readings were then made at the surface and 1-, 2-, 3-, and 4-in. depths, both before and after remolding with 100 blows of the remolding hammer. For sand with fines, poorly drained, or similarly suspect soils, the vibrated remolding test (i.e., the cylinder is dropped 6 in. 25 times) replaced the drop hammer test. The RI for a block was computed by dividing the summation of "after" CI readings by the summation of "before" readings of the remolding tests on the 6- to 12-in. layer (critical layer). The RI values were averaged for each visit. RCI is the product of the site CI for the 6- to 12-in. layer and the RI of each visit.

Surface shear strength

35. The surface shear strength was measured with the Cohron sheargraph[12] at one square in each block, on each of four visits. The visits were selected to give a range of measurements within the capabilities of the instrument. Three tests were run. Two were soil-to-soil shear; the first, using a clean vaned head, determined peak shear strength at initial soil failure; the second, by continuing the test, determined ultimate shear strength during head rotation. The third test was rubber-to-soil, using a flat rubber insert to determine shear strength during head rotation. Peak strength was measured once in each sampling square, each time at a different load, 5, 10, or 15 psi. Ultimate soil-to-soil and rubber-to-soil shear were measured at separate locations in each sampling

square with 5-, 10-, and 15-psi normal loads. To determine moisture content, soil samples were taken from the vaned head and 1/4 in. below the two locations in each square where the shear tests were made.

Other factors

36. Other factors that change with time and weather conditions, including depth to groundwater, depth of surface water, surface conditions, and vegetation, were measured, and any unusual circumstances noted, as on the daily schedule (paragraphs 22-30).

Single Measurements

37. Certain data are needed to determine soil moisture and soil strength prediction relations for analogous areas that are not required to determine such relations for a given site. For this reason, soils were classified and described from analyses of physical properties of bulk samples and natural soil cores. These data are given in table 2.

Bulk soil samples

38. One-quart bulk samples were taken from the surface to 6-in., 6- to 12-in., and 12- to 18-in. layers from one location for each block of a site (fig. 1). The Atterberg limits were determined using field-moist soil; grain-size distribution was determined by sieve and hydrometer, using oven-dried soil; and total organic content was determined using the acid digestion method. In addition, specific gravity was determined for selected samples; the 3- and 15-atm soil moisture tension values were measured using field-moist soil repacked in a pressure-membrane cell; acidity (pH) was measured using a glass electrode; and the electrical conductivity (EC) of 1:1 equivalent soil extract was used to determine soluble salts. Soil property determinations of the 12- to 18-in. layer were not made.

Soil core samples

39. Core samples were taken from one location in each block by 3-in. layers from the surface to 18 in. A modified San Dimas sampler was used to obtain undisturbed cores 2 in. in diameter and 1-3/8 in. high. The tension table was used to determine moisture tension values at 0 atm

(saturation) and 0.06 atm (60-cm water differential). Bulk density (dry unit weight) was obtained from the samples after completion of the tension tests.

PART IV: SOIL STRENGTH

Determination of Strength-Moisture Relations

40. Both bearing and traction capacities of a soil are reflected by its strength. The relation of strength to moisture is generally inverse; i.e. as moisture increases, strength decreases. A mathematical equation expressing this relation is desirable when correlating moisture-strength changes with soil characteristics in developing methods for forecasting trafficability. Natural variations of soil properties, particularly moisture content, obscure the proper mathematical form expressing the moisture-strength relation; however, previous studies[13] have indicated that a logarithmic relation can be reasonably fitted for most sets of data.

Equations derived

41. Equations were determined by using logarithmic values and calculating the linear regressions using the method of least squares.[14] With either moisture content or strength as the dependent variable, two lines can be derived as shown by dashed lines in fig. 4. As data variability increases, the two derived lines diverge more. The desired relation, log RCI or CI as a function of log MC, has the flatter slope and this would become even flatter if additional data were obtained that increased variability; however, even with the data available, the relation yields estimates of high CI or RCI at high MC, the critical condition at which accurate estimates are desired for trafficability purposes. A more realistic estimate of CI or RCI was believed to be obtained by using a modified slope, calculated as the square root of the ratio

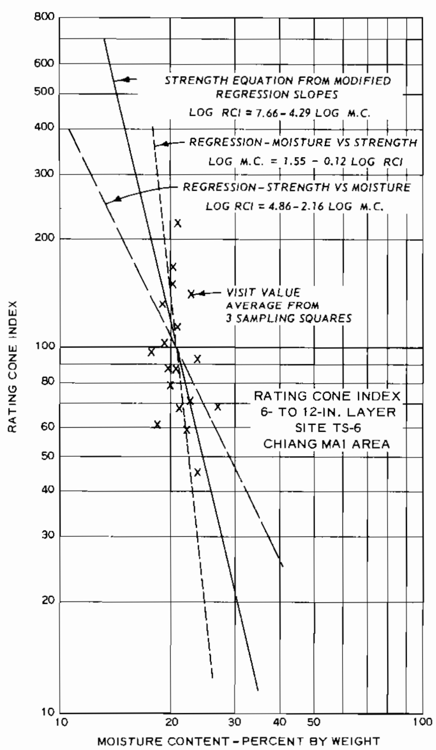

Fig. 4. Derivation of strength equation

of the two regression slopes, and fitting the equation at the mean (solid line in fig. 4). Equations thereby derived from site values are called specific equations and are the equations used in subsequent analyses.

Correlation coefficients determined

42. The correlation coefficients for the data points (RCI and CI versus MC) were calculated for each site to determine the existence and degree of correlation among strength-moisture values. The correlation coefficient is a number related to the alignment of data points and provides a measure of probability of occurrence of a spurious correlation.[14] If the probability of the correlation being spurious was low, at the 0.01 to 0.05 probability level, the correlation was considered highly significant or significant, respectively, and a line could be fitted to the data with confidence. If the probability that a spurious correlation existed was greater than the 0.05 level, the correlation was considered nonsignificant, and a line could not be computed with confidence. For all sites with significant correlations, lines were fitted to the data points (RCI and CI versus MC) using logarithmic coordinates and the modified slope discussed in the preceding paragraph. Sites with nonsignificant correlations were fitted visually (omitting stray values). For some sites there were not sufficient points to derive a relation either way.

CI range and CI-MC relations

43. Range of CI. The number of measurements made at each site, range of CI values, and MC-CI relations are given in table 3. The tabulations of range and distribution of CI measurements within certain increments show that for 67 of the 75 sites listed there were at least 12 measurements, or approximately one each month, which are enough to characterize CI for the period of record. It may be seen from the tabulation that 16 sites had CI's of less than 80 on at least one visit. A site with a measured CI less than 80 at least once is considered in this study to be a site with a potential trafficability problem at some time during a year's period. Forty-nine of the 67 sites also had measured CI's greater than 750 at least once during the period of record. The results show the wide range in strength that generally occurs.

44. CI-MC relations. In determining CI-MC relations, CI values

greater than 749 were not used. The correlation coefficients usually were significant, demonstrating that a good relation generally exists between CI and MC. Fifty-seven of the 75 sites had highly significant correlations; six, significant; ten, nonsignificant; and two sites were not considered because strengths were too high to measure. For the ten nonsignificant sites (table 3), a visual line of best fit was drawn rather than computing the relation. One of the two firm sites, TS 25, contained ML soil with a silt content of 78% and a bulk density of 1.78 g/cc (111 pcf), the highest in this study. The high density and correspondingly low pore saturation of 17% undoubtedly contributed to the high strength, an uncommon soil in the areas investigated. The other firm site, TS 18, contained CL-ML soil whose properties were within the range normally encountered in this soil type. An explanation for its continued firm condition is obscure; other CL-ML soils became quite soft. Both sites had recently been under rice culture, and were subject to flooding for prolonged periods.

45. Examples of CI and MC values and derived relations are given in plate 5. The scatter of data points is typical, and the correlations are considered highly significant. For three sites, the derived logarithmic curve fits the data better than any other; however, for site PD 241 a linear curve would have fitted the data just as well.

RI range and RI-MC relations

46. Range of RI. Data considered in the analysis of RI are given in table 4. Sites TS 18 and 25 were too firm for RI to be measured. Of the 73 sites with measured data, 26 (36%) had mean RI values (combining all visits) below 1.00, but only three were below 0.50. By visit values, 54 sites had some RI values below 0.80, and 19 sites had some below 0.50. For all RI measurements, 24% were less than 0.80, 42% were between 0.80 and 1.20, and 34% exceeded 1.20.

47. RI-MC relations. RI data were scattered and generally showed no significant correlation with MC (see plate 5). The poor correlation precluded the use of derived equations for analysis purposes; however, for those sites with significant correlations, a simple linear regression was computed, for which the slope indicated the change of RI per unit

change of MC. The equation constants are shown in table 4. For comparative purposes, the range and mean RI values were determined for each site. Although it is probable that some general trend of decreasing RI with increasing MC exists, the relation is not well defined within the range of MC being considered.

RCI range and RCI-MC relations

48. Range of RCI. The number of measurements, distribution of RCI values, and RCI-MC relations are given in table 5. Since difficulty was experienced in obtaining RI measurements on each visit, the number of RCI values used in the analysis was usually less than the number of CI values. Examination of the distribution of measurements into arbitrary RCI increments shows that 73% of the values are above 161 which indicates firm soil with little or no soil trafficability problems on level terrain. However, 26 sites (36%) had some RCI measurements less than 60 and 5 sites had some RCI less than 26 indicating that at some time during the year soil trafficability problems do exist.

49. RCI-MC relations. The number of measurements used in correlations is less (for most sites) than the total number of measurements since values of 750+ CI were not used. RCI values greater than 750 were used, however, if produced by a CI value less than 750 multiplied by an RI value greater than 1.00. Forty-five sites had RCI-MC relations that produced highly significant correlation coefficients, 10 sites were significant, and 17 nonsignificant. The relations were not as good as the CI relations because of variations in RI. Specific logarithmic equations were derived for sites with significant and highly significant correlations. Curves of best visual fit were drawn for 13 of the 17 sites with nonsignificant correlations; the four remaining sites had only high strength values or had too few points to permit drawing a curve.

50. The steepness of the curves and the scatter of data used in curve derivation reveal that a change of 1% or 2% in moisture content, which can occur because of the vagaries of wetting and drying or other natural differences from spot to spot, results in a discrepancy of 50 RCI units from the curve, yet the single value and the curve representing the average change in conditions are both valid. The slopes of

the RCI-MC relations generally are steeper than those for CI-MC, expressing a greater change of RCI with unit change in MC. Examples of RCI-MC relations are shown in plate 5. There was a marked reduction in strength with a small increase in moisture which is typical of the very fine sand-to-silt found in the low terraces of Thailand. At site PD 241, for example, RCI decreased from 300 to 50 with an increase of 4.5% MC. The middle terrace soils, such as that at TS 31, with higher sand content, had a smaller, but still large rate of RCI change. RCI decreased from 300 to 50 with a 5.5% moisture increase. The soils of the hills and mountains (sites TS 3 and 47) and the alluvial soils of the valleys showed less response, changing roughly 20 to 40 units at the 100 and 250 RCI levels, respectively, for each 1% change in moisture.

Soil Strength in Thailand

51. To determine areas in Thailand where low soil strength could be a problem from a trafficability standpoint, minimum RCI values (table 5) were grouped and analyzed by study areas and by classes of commonly observed soil or site characteristics including grain size, plasticity, organic content, pedological designation, wetness index, geomorphic groups, and land use. Both measured and estimated values are listed in the tabulations in subsequent paragraphs. Estimated minimum RCI was determined by reading the RCI-MC curves at field maximum moisture content. For most TS sites the field maximum moisture content values were estimated. In most cases the trends of measured and estimated values are similar, but it is recognized that estimated values may be in error for some sites because of either or both an incorrect RCI-MC relation (although significant for the data from which derived) or a faulty maximum moisture content estimation. Worth noting are the relatively low estimated averages for all areas, indicating the prevalence of low soil strengths and, therefore, poor trafficability at some time everywhere in the country.

Minimum RCI by study areas

52. In each study area, sites in level to rolling terrain were selected to represent the dominant soils and also soils of less extent, but of suspected critical (low) strength. Bogs, swamps, and soils on steep

and precipitous areas were purposely excluded. Average minimum RCI values, measured and estimated, are shown in the following tabulation.

Study Area	No. of Sites Used	Average RCI 6- to 12-in. Layer Minimum Measured	Minimum Estimated	Sites Too Firm to Obtain Reliable MC-RCI Relations
Chiang Mai	12	88	56	TS 1
Khon Kaen	12	108	58	PD 246
Nakhon Sawan	6	146	41	TS 18
Lop Buri	12	106	62	TS 25
Bangkok	3	42	50	
Pran Buri	6	46	40	PD 257
Chanthaburi	10	73	78	
Hat Yai	7	98	75	TS 44, 45

53. Average minimum measured RCI for the four northern study areas tended to be higher than for the southern study areas. However, average estimated minimum RCI values indicated that soils of the northern areas were as weak as those of the southern areas. The differences in minimum measured RCI values are believed to have been caused by insufficient sampling in the northern areas during high soil-moisture-content periods.

Minimum RCI by soil property groups

54. Grain size. Soils were grouped by grain size at levels used to divide classes in the USDA textural classification, and the results are given in the following tabulation.

Range of Grain Size %	No. of Sites	Average RCI 6- to 12-in. Layer Minimum Measured	Minimum Estimated	Sites Too Firm to Obtain Reliable MC-RCI Relations
Sand:				
0-19	14	93	45	TS 25
20-49	31	76	49	TS 1
50-89	22	109	78	PD 246 and 257, TS 18, 44, and 45
90+	1	201	185	

(Continued)

Range of Grain Size %	No. of Sites	Average RCI 6- to 12-in. Layer Minimum Measured	Minimum Estimated	Sites Too Firm to Obtain Reliable MC-RCI Relations
Silt:				
0-29	24	115	84	PD 246 and 257, TS 18 and 45
30-49	39	81	47	TS 1 and 44
50-79	36	66	22	TS 25
Clay:				
0-9	9	134	95	PD 246 and 257
10-26	29	69	39	TS 1, 18, 25, 44, and 45
27-39	19	102	77	
40+	11	105	54	

55. Soils whose strength remained high throughout the study were generally high in sand content. The average estimated minimum RCI decreased with decreasing sand content and was lowest at sand contents less than 50%. The opposite was true for silt; minimum RCI decreased as silt content increased. Average RCI was critically low when silt content was above 30%, and extremely low in the 50% to 79% range. However, the site with the highest silt content, TS 25, which had 78% silt in the 6- to 12-in. layer, remained firm throughout the testing period, since relatively pure silts can compact into a dense, low permeability, firm material. In the clay group the lowest RCI occurred in soils with 10% to 26% clay content. The soils with clay content greater than 40% included marine and alluvial clays of low RCI and upland clays high in iron compounds that remained fairly firm. Five of the 11 sites in this group had measured minimum strengths less than 60 RCI. The weakest soils were those with mixtures of grain sizes that contained less than 50% sand, 30% to 70% silt, and 10% to 26% clay.

56. Liquid limit and plasticity index. Sites were grouped by liquid limit and plasticity index as follows:

Range of	No. of Sites	Average RCI 6- to 12-in. Layer: Minimum Measured	Average RCI 6- to 12-in. Layer: Minimum Estimated	Sites Too Firm to Obtain Reliable MC-RCI Relations
Liquid limit:				
Nonplastic	6	154	131	PD 257
1-30	30	74	44	PD 246 and TS 1, 18, 25, 44, and 45
31-49	13	103	48	
50+	19	97	70	
Plasticity index:				
Nonplastic	11	122	80	PD 246 and 257 and TS 25
1-7	15	74	51	TS 18
8-21	20	79	50	TS 1, 44, and 45
22+	22	104	64	

For both properties, the highest minimum RCI values occurred in the nonplastic soils; the lower RCI values occurred in the groups with lowest liquid limits and plasticity indexes. The five sites with low liquid limits and no plasticity index (not shown in above tabulation) had an average minimum RCI of 20. The transition from a high strength soil to a low strength soil is narrow and the properties that determine the transition are not defined. For example, site TS 25, which had high RCI values at all times, also had a low liquid limit value and no plasticity index. Most of the continually firm soils were in the low liquid limit range. Within the range of soils that had both liquid limits and plasticity indexes, minimum RCI values increased with increased plasticity.

57. Organic content. The average minimum RCI's were next grouped by 1% increments of organic content.

Range of Organic Content %	No. of Sites	Average RCI: Minimum Measured	Average RCI: Minimum Estimated	Sites Too Firm to Obtain Reliable MC-RCI Relations
0.00-0.99	33	85	55	PD 246 and 257 and TS 18, 25, and 44
1.00-1.99	20	83	62	TS 45
2.00-2.99	9	140	68	TS 1
3.00-3.99	3*	98	42	
4.00-4.99	2	46	42	

* Site TS 50 (SP-SM) with high sand content and high strength omitted.

Most of the sites had less than 2% organic content, only five had more than 3%, and none exceeded 5%. This array does not show clearly the organic content effects; however, minimum RCI's were lowest for the groups with more than 3% organic content.

Minimum RCI by pedological classes

58. The average minimum RCI's were arranged by soil orders and great soil groups of the USDA pedological classification as shown in the following tabulation.

Pedological Class: Suborder	Pedological Class: Great Soil Group	No. of Sites	Average RCI 6- to 12-in. Layer: Minimum Measured	Average RCI 6- to 12-in. Layer: Minimum Estimated	Sites Too Firm to Obtain Reliable MC-RCI Relations
Zonal Order					
Soils of the forest grassland transition	Noncalcic Brown	2	32	18	
Light colored podzolized soils of the timbered regions	Gray Podzolic	6	70	47	PD 246
	Red-Yellow Podzolic	4	98	108	TS 44 and 45
Lateritic soils of forested warm-temperate and tropical regions	Reddish-Brown Lateritic	3	86	114	
	Red-Brown Earth	5	195	78	
	Red-Yellow Latosol	4	70	76	
	Red-Brown Latosol	1	69	81	
Intrazonal Order					
Halomorphic (saline and alkali) soils	Solodized-Solonetz*	3	181	122	
Hydromorphic soils	Humic Gley	5	103	55	
	Low-Humic Gley	14	66	25	TS 18 and 25
Calcimorphic soils	Grumusol	2	92	72	
Azonal Order					
	Regosol and related soils**	2	196	150	PD 257
	Alluvial	16	79	44	TS 1
Made Land					
	Completely mixed and/or transported by man	1	35	50	

* Includes site TS 11, Low-Humic Gley saline phase, with a high salt content.

** Includes sites TS 9, Regosolic Gray Podzolic, and TS 50 Ground-Water Podzol with no cemented hardpan.

The zonal order includes soils with normal drainage and well-developed profiles influenced largely by climate and vegetation. The intrazonal order includes soils with developed profiles reflecting a strong influence from relief, parent material, or age that results in imperfectly drained soils. Soils of the azonal order have little or no profile development and are found in recent depositions or in older materials with excessive drainage. The made-land site, TS 8, was on the cultivated ridges near Bangkok.

59. Each order has one or two great soil groups with critically low average minimum RCI's. The Noncalcic Brown and Gray Podzolic soils of the zonal order occupy flats and slopes of the terraces. Five of the eight sites in these two groups were located in the western end of the Chanthaburi area and in the Pran Buri. Both study areas are in the driest climate in Thailand, but both also have some of the weakest soils when wetted. Generally, these soils do not have water tables near the ground surface. The Humic Gley and Low-Humic Gley groups have the lowest minimum RCI's for soils of the intrazonal order. These soils occur in the lower terraces and are naturally poorly drained, with water tables that rise to the surface during the monsoon season. They are commonly diked for rice culture. The Alluvial soils of the azonal order are mixed in texture and strength, and include areas that are natural levees, local alluvium, and bottomlands. Most are influenced by water tables near the surface and most have low minimum RCI's.

60. The great soil groups that have high average minimum RCI's and may be considered trafficable at all times are the red and yellowish soils of the high terraces and hills in the zonal order; the Grumusols, which are stiff clays derived from calcareous material in plateaus in the intrazonal order; the Regosols, which are sandy soils in the azonal order; and the saline and alkaline soils that occur often in semiarid to arid climates where surface or seepage water collects and evaporates.

Minimum RCI by site characteristics

61. Wetness index (WI). The WI is governed by the depth of wetting and maximum height of the water table (paragraph 6). Sites were grouped by WI as follows:

WI	No. of Sites	Average RCI 6- to 12-in. Layer Minimum Measured	Minimum Estimated	Sites Too Firm to Obtain Reliable MC-RCI Relations
2	20	100	89	PD 246 and 257 and TS 1, 25, 44, and 45
3	11	103	44	
4	37	86	48	TS 18

Two-thirds of the sites were influenced by water tables (WI 3 and 4), and had critically low minimum RCI averages. The fully wetted but drained sites (WI 2) usually had a high minimum RCI average; however, eight of the 20 sites in this category had estimated minimum RCI's of less than 60, with an average minimum RCI of 32. Although sites with water tables generally have low soil strengths, the results of this study show that the strength of certain drained sites with no water table can become critically low when fully wetted by rainfall.

62. Geomorphic groups. The sites were grouped by obvious terrain features as follows:

Geomorphic Groups	No. of Sites	Average RCI 6- to 12-in. Layer Minimum Measured	Minimum Estimated	Sites Too Firm to Obtain Reliable MC-RCI Relations
Mountains	1	73	58	
Hills-plateaus	13	125	90	TS 44 and 45
Upper terrace	4	112	112	
Middle terrace	10	69	45	PD 246
Lower terrace	14	66	25	TS 18 and 25
Depression	3	114	32	
Floodplain	19	77	49	TS 1
Back beach	1	201	185	PD 257
Salt soils	3	131	112	

The average lowest minimum RCI's were found for the middle and lower terraces, depressions, and floodplains. Highest minimum RCI's occur in the hills-plateaus, back beaches, and salt soils. Although the mountain areas are generally steep and stony with thin soils and firm conditions, the one mountain site indicates that areas of ridges and spurs with deep soils can become a soil trafficability problem. This is significant since ridges and divides are commonly used for trails in undeveloped areas.

63. Land use. The sites were arranged according to land use as follows:

Land Use	No. of Sites	Average RCI 6- to 12-in. Layer Minimum Measured	Minimum Estimated	Sites Too Firm to Obtain Reliable MC-RCI Relations
Undisturbed	9	110	61	TS 44
Tree plantations	11	83	95	TS 45
Lawn	5	124	76	PD 246 and 257 and TS 1
Grazed	8	66	42	
Cultivated-fallow	5	112	78	
Cultivated (excluding rice)	7	118	56	
Cultivated-rice (current or recent)	22	71	33	TS 18 and 25 and PD 249*

* Site 249 salt soil not representative.

Rice lands had lowest minimum RCI's, followed by lands used for grazing and other cultivation. The low average for grazing land can be attributed to silty soils influenced by water tables. Half were fenced on experiment stations and probably had been planted in rice previously. Tree plantations, lawns, and undisturbed soils had higher minimum RCI values. The undisturbed group included two local alluviums and three middle terrace soils that produced an average minimum RCI that was lower than minimum RCI's for the tree plantations and lawn sites.

PART V: PREDICTION OF SOIL MOISTURE

Soil Moisture-Prediction Method

Background

64. As used herein, the word "prediction" does not have the usual connotation of forecasting events before they happen. Actual measurements of soil moisture content were made in this study; hence, there was no need to "predict" in the usual sense of the word. Known rainfall amounts and prediction factors are used in combination, as described in paragraphs 65-72, to compute values of moisture content on a day-by-day basis. The computed values are called "predicted values" in this and other WES reports to date. A continuous "prediction" always begins with a known (measured) value of soil moisture content, utilizes measured rainfall amounts, and employs prediction factors developed at the site for which "predictions" are being made. In a practical situation, it would be necessary to estimate a starting moisture content, use deduced or estimated prediction factors, and forecast daily rainfall amounts. Otherwise, the procedures and techniques for predicting soil moisture content and strength are exactly the same in the research and practical application stages.

Principles

65. The WES soil moisture-prediction method is a "bookkeeping" system that accounts for accretion and depletion of soil moisture in the 0- to 6-in. and the 6- to 12-in. soil layers on a daily basis. The basic method apparently would be applicable for other layers provided the necessary prediction factors were developed. The method is based on studies that show that accretion of soil moisture is related to rainfall and depletion of soil moisture is related to evaporation, transpiration, and drainage. Daily moisture content is predicted by accreting soil moisture for each rainstorm (according to a certain pattern) and depleting soil moisture between rainstorms (according to other experimentally established relations). The method is described in detail in references 3 and 4.

Prediction factors
for Thailand PD sites

66. The factors needed to make a prediction of soil moisture are (a) initial moisture content, (b) field-maximum moisture content, (c) field-minimum moisture content, (d) minimum-size storm, (e) daily rainfall, (f) accretion relations, (g) depletion relations, and (h) transition dates. These factors were derived for each site from the detailed data collected at the site (see Vol II). Prediction factors were not determined for two sites due to improper electrical resistance unit response. Units at site PD 249 were uprooted by vandals and did not function consistently after reinstallation, and units at PD 245 did not respond consistently by depth, suggesting an improper placement.

67. Initial moisture content. The moisture contents measured at the sites were used as the initial moisture contents. The starting dates of record for these predictions and the measured moisture contents on those dates at each of the PD sites were as follows:

PD Site No.	Date of Initial Measurement	Initial Measured Moisture Content, in./6 in. of Soil: 0 to 6 in.	Initial Measured Moisture Content, in./6 in. of Soil: 6 to 12 in.
241	4 May 64	1.97	1.59
242	16 May 64	0.86	0.59
243	4 May 64	2.08	1.81
244	1 Aug 64	3.09	3.01
246	6 May 64	1.36	1.09
247	6 May 64	1.02	1.42
248	6 May 64	1.45	1.39
251	1 Aug 64	1.68	1.85
252	1 Aug 64	1.95	2.44
253	25 Aug 64	1.50	1.92
254	1 Aug 64	1.60	1.83
255	6 June 64	1.81	1.86
256	6 June 64	2.53	2.29
257	1 May 64	0.46	0.30
258	22 July 64	2.76	2.52
259	1 Aug 64	2.49	2.47
260	14 Aug 64	1.02	0.79

68. Field-maximum and field-minimum moisture contents. The field-maximum and field-minimum moisture contents obtained from examination of

the soil moisture records for the PD sites were as follows:

PD Site No.	Moisture Content, in./6 in. of Soil			
	Field Maximum		Field Minimum	
	0 to 6 in.	6 to 12 in.	0 to 6 in.	6 to 12 in.
241	2.38	2.05	0.62	0.61
242	1.55	1.27	0.18	0.19
243	2.25	1.97	0.40	0.41
244	3.09	3.01	1.41	1.66
246	1.43	1.43	0.17	0.23
247	1.67	1.73	0.31	0.48
248	2.10	1.85	0.24	0.16
251	1.96	2.10	0.60	1.02
252	2.65	2.88	1.27	1.99
253	2.70	2.56	1.23	1.67
254	2.00	2.18	0.80	1.30
255	2.22	2.26	0.75	0.87
256	2.62	2.35	1.00	1.31
257	1.22	1.18	0.07	0.14
258	2.85	2.60	1.38	1.44
259	2.52	2.59	1.22	1.51
260	1.31	1.46	0.40	0.54

69. Minimum-size storm. A minimum-size storm is one from which no accretion or depletion of soil moisture will occur. Its size depends principally upon the type and amount of vegetation cover. The minimum-size storm for each PD site was obtained using procedures outlined in reference 3. The minimum-size storms derived from the data for the PD sites are tabulated below.

PD Site No.	Minimum-Size Storm, in.	PD Site No.	Minimum-Size Storm, in.
241	0.15	253	0.15
242	0.10	254	0.10
243	0.15	255	0.15
246	0.15	256	0.15
247	0.15	257	0.10
248	0.10	258	0.20
249	0.15	259	0.20
251	0.15	260	0.10
252	0.15		

70. Daily rainfall. Daily rainfall amounts obtained from rain gages located at each PD site were used for soil moisture content predictions (see paragraph 26).

71. <u>Accretion relations.</u> Previous studies have shown that the amount of water taken up by a soil depends primarily upon the amount of rainfall and the amount of space in the soil available for storing the water. Accretion is divided into two classes, I and II, depending on whether rainfall is less or more, respectively, than the available storage in the 0- to 12-in. soil layer. A set of data relations for one site (PD 254) is shown in fig. 5 as an example. The accretion relations derived for the 17 Thailand PD sites are shown in table 6.

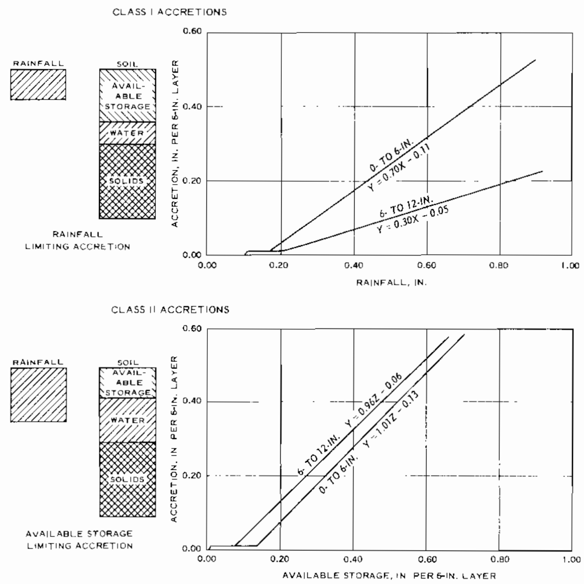

Fig. 5. Soil moisture accretion relations, site PD 254

72. <u>Depletion relations and transition dates.</u> Depletion is the net loss of water from the soil layers on days between accretions. From the record of daily soil-moisture contents, specific depletion curves were developed for the 0- to 6-in. and the 6- to 12-in. soil layers at each of the PD sites. The depletion curves were constructed according to procedures outlined in reference 3. In this procedure, average depletion curves were developed from a family of depletion curves traced from the record of depletion of soil moisture versus days for the periods between rains. Depletion rates were different between seasons (transition dates) and layers, requiring separate curves. The seasonal differences are caused by relatively large changes in the weather including temperature, humidity, solar radiation, etc., which influence evaporation, and in some climates by the growth or dormancy of vegetation, both of which have a marked effect on transpiration. Since the curve segments are traced within a season, each season must be determined before the final depletion curves are derived. Temperate climates have marked seasons, and initial curves are derived for June, July, and August as summer, and December, January, and February as winter. Then, the spring-autumn transition depletion curves are derived

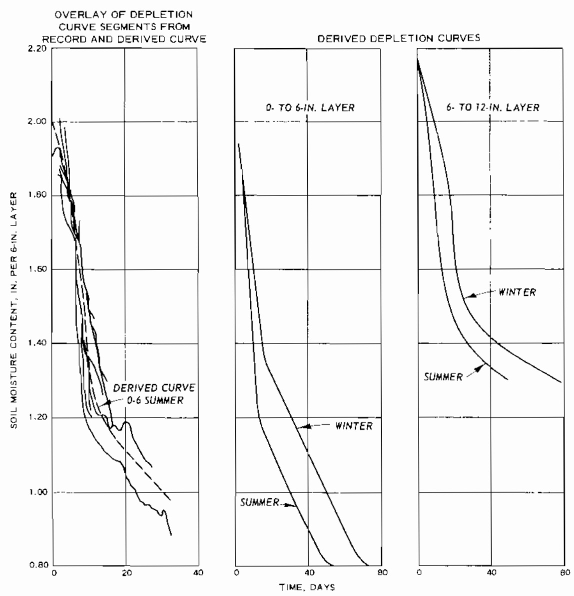

Fig. 6. Soil moisture depletion relations, site PD 254

from the intervening periods of record. In Puerto Rico,[6] Hawaii,[15] and Panama,[16] one depletion curve was found to apply for each site throughout the year. Derivation of one depletion curve was tried initially in the Thailand study, but loss rates from November to February were found to be less than those during the other months, so winter and summer curves were derived. The transition dates are tabulated below with most sites having a 1 November winter date and a 1 March summer date. The dates were not readily discerned. An example of a family of derived depletion curves is shown in fig. 6. The cumulative daily depletion from field-maximum moisture content is listed in table 7 for each site and soil layer.

PD Site No.	Transition Dates First Day Winter	Summer	PD Site No.	Transition Dates First Day Winter	Summer
241	1 Nov	15 Feb	253	1 Nov	1 Mar
242	1 Nov	1 Mar	254	27 Oct	6 Mar
243	1 Nov	1 Mar	255	1 Nov	15 Feb
244	1 Nov	1 Mar	256	1 Nov	1 Mar
246	1 Nov	1 Mar	257	1 Nov	1 Mar
247	1 Nov	1 Mar	258	1 Nov	1 Mar
248	1 Nov	1 Mar	259	1 Nov	1 Mar
251	1 Nov	15 Feb	260	1 Nov	1 Mar
252	1 Nov	1 Mar			

Water table effects

73. From previous studies in the United States,[3] it has been demonstrated that groundwater tables in or near the 0- to 12-in. layer of soil influence the soil moisture depletion rates in that layer, especially if the water table recession is impeded. For this reason, soil moisture and water table data from the Thailand PD sites were examined for instances

when the elevation of the water table affected depletion rates. For sites with water tables near the ground surface, the moisture content followed the pattern of the water table rather than rainfall. When the water table remained near the ground surface between rains or for a period after the rainy season stopped, the moisture content persisted at a high level. When the water table receded slowly, the soil drying rate was slow compared to that with a fast receding water table or with no water table present. When the water table rose abruptly, the moisture content increased in some instances more than accountable from rainfall at the site. However, the water table generally responded to the rainfall measured at the site, but lagged depending on the water requirement for recharge and on the surface and internal drainage of the soil. For periods when the water table did not influence the surface soil layers, and for soils with a rapidly rising and falling water table, soil wetting and drying were similar to that of a drained soil. Hence the water table influence is a complicating factor only for certain soils at certain times. Methods for modifying the prediction during lag periods of water table influence are being developed; however, a general method has not been devised so no modifications in prediction to correct for water table influence were attempted in this study.

Prediction of Soil Moisture for Thailand PD Sites

Comparison of predicted and measured values

74. The specific site factors listed in paragraph 66 were used to predict moisture contents for the 17 PD sites. Plate 6 shows graphically the day-by-day comparisons at three sites between predicted and measured moisture contents for the 6- to 12-in. soil layer only. Also shown on the graphs are rainfall data and water table data for the respective sites and dates. Predictions were continuous from the starting date to the termination of data collection.

75. The average deviations of predicted from measured moisture contents determined for each site and soil layer are shown in the following tabulation:

PD Site No.	No. of Measurements	Soil Moisture Deviations, in./6-in. Layer, at All PD Sites: 0- to 6-in. Layer Absolute	0- to 6-in. Layer Algebraic	6- to 12-in. Layer Absolute	6- to 12-in. Layer Algebraic
241	485	0.27	-0.03	0.42	-0.42
242	474	0.25	-0.21	0.22	-0.21
243	491	0.48	-0.45	0.35	-0.35
244	392	0.63	-0.61	0.66	-0.66
246	491	0.17	-0.08	0.16	-0.12
247	491	0.24	-0.03	0.27	-0.26
248	489	0.32	-0.10	0.24	-0.17
251	424	0.09	-0.02	0.06	+0.01
252	441	0.08	-0.01	0.08	+0.01
253	415	0.10	-0.03	0.07	+0.01
254	419	0.09	+0.03	0.07	-0.01
255	496	0.11	-0.02	0.11	-0.08
256	495	0.15	-0.04	0.07	-0.03
257	497	0.10	-0.05	0.06	+0.01
258	429	0.18	-0.13	0.12	-0.07
259	416	0.12	-0.07	0.05	-0.03
260	380	0.18	-0.08	0.14	-0.10
	Average	0.21	-0.11	0.19	-0.15

76. Prediction accuracy is considered good when the average algebraic deviations approach zero and the average absolute deviations are 0.10 in. of water per 6-in. soil layer or less. From the above tabulation it can be seen that the average absolute and algebraic deviations for the 17 PD sites are much larger than the above-stated limits. However, the above tabulation includes sites with water tables and, as mentioned previously, the effects of water tables were not included in the prediction of soil moisture for these sites. To demonstrate the water table effect, a second prediction for the water table sites was made using only long periods when the water table was below the 12-in. depth. The periods and results are presented below.

Site	Prediction Periods with Water Table Below 12-in. Depth
241	4 May - 29 Aug 64, 22 Oct 64 - 22 May 65
243	21 May - 29 Aug 64, 22 Oct 64 - 23 July 65
247	6 June - 4 Aug 64, 8 Dec 64 - 27 Aug 65
248	6 May - 4 Aug 64, 13 Nov 64 - 27 Aug 65
252	1 Aug - 17 Sept 64, 26 Oct 64 - 26 Aug 65
255	6 June - 13 Sept 64, 30 Oct 64 - 19 June 65
256	6 June - 23 Sept 64, 21 Oct 64 - 7 June 65, 3 July - 22 Aug 65

PD Site No.	Period of Record (1st Prediction): No. of Measurements	Soil Moisture Deviations in./6-in. Layer: Absolute 0- to 6-in.	Absolute 6- to 12-in.	Algebraic 0- to 6-in.	Algebraic 6- to 12-in.	Periods with Water Table Below 12-in. (2d Prediction): No. of Measurements	Soil Moisture Deviations in./6-in. Layer: Absolute 0- to 6-in.	Absolute 6- to 12-in.	Algebraic 0- to 6-in.	Algebraic 6- to 12-in.
With water table:										
241	485	0.27	0.42	-0.03	-0.42	303	0.21	0.17	-0.06	-0.17
243	491	0.48	0.35	-0.45	-0.35	341	0.32	0.17	-0.28	-0.16
244	392	0.63	0.66	-0.61	-0.66	--	--	--	--	--
247	491	0.24	0.27	-0.03	-0.26	303	0.14	0.13	-0.01	-0.12
248	489	0.32	0.24	-0.10	-0.17	358	0.22	0.21	-0.09	-0.13
252	441	0.08	0.08	-0.01	+0.01	350	0.08	0.07	+0.02	+0.03
255	496	0.11	0.11	-0.02	-0.08	332	0.10	0.07	+0.01	-0.03
256	495	0.15	0.07	-0.04	-0.03	340	0.12	0.06	+0.02	-0.02
	Average	0.28	0.28	-0.16	-0.24		0.17	0.13	-0.06	-0.09
Without water table:										
242	474	0.25	0.22	-0.21	-0.21					
246	491	0.17	0.16	-0.08	-0.12					
251	424	0.09	0.06	-0.02	+0.01					
253	415	0.10	0.07	-0.03	+0.01					
254	419	0.09	0.07	+0.03	-0.01					
257	497	0.10	0.06	-0.05	+0.01					
258	429	0.18	0.12	-0.13	-0.07					
259	416	0.12	0.05	-0.07	-0.03					
260	380	0.18	0.14	-0.08	-0.10					
	Average	0.14	0.11	-0.07	-0.06					

77. From the above tabulation it can be observed that the average deviations for most water table sites were large with the first prediction, as expected, since the prediction method requires depletion between storms even when the water table maintains moisture contents at a high level. Three sites, PD 252, 255, and 256, had fair accuracy; the water table responded readily, keeping in phase with the depletion curves between storms. Site PD 244 had only brief periods with no water table and was not retested. The results of the second prediction in the above tabulation show considerable improvement for the initially poor predictions and not much change for the sites with fair accuracy. Allowance for persisting water tables in the surface foot would improve predictions for certain water table sites, and a means for distinguishing sites with a persisting water table is needed.

78. Predictions for five of the well-drained sites had fair

accuracy, and for four were poor. Much of the error for site PD 242 originated during the last 3 months of the record, apparently due to low predicted accretion during the rainy season. The class I accretion relations for this site had low slopes compared to other sites, as shown in table 6. For site PD 246, the predicted depletion rates were too high during some periods of the record. The absolute deviations averaged for the nine drained sites, namely 0.14 in. for the 0- to 6-in. layer and 0.11 in. for the 6- to 12-in. layer, compare favorably with those of previous studies, i.e. with 0.10 and 0.08 in. for 118 sites in the United States,[4] and 0.09 and 0.07 in. for eight sites in Puerto Rico,[6] for respective 6-in. layers.

79. In the examples of records of predicted versus measured moisture content for the 6- to 12-in. layer shown in plate 6, site PD 254 (fig. a) demonstrates the fair prediction accuracy of sites with no water table. A site with a generally responsive water table, PD 255 (fig. b) shows fair accuracy during most of the record. The big discrepancy originated in late October at the end of the rainy season, when measured moisture remained high for 2 weeks while depletion was predicted. The discrepancy was continued until the field minimum was reached, 2 months later. A site with a slowly responding water table, PD 243 (fig. c), shows the poor prediction for sites needing an adjustment for water table.

Comparison of average accretion in Thailand with that of the western hemisphere

80. The average accretion relations derived from previous tests in the continental United States,[5] Alaska,[17] Puerto Rico,[6] and Hawaii[15] are compared to the average accretion relations of the Thailand prediction sites below. The average equations were solved for estimated accretion after 1 in. of rainfall for class I accretions and for 1 in. available storage for class II accretions with the results shown on the following page. The results show that the wetting characteristics of the Thailand sites were essentially the same, on the average, as those found in the United States and elsewhere.

Area	Class I: No. of Sites	Class I: Average Accretion 0- to 6-in. Layer	Class I: Average Accretion 6- to 12-in. Layer	Class II: No. of Sites	Class II: Average Accretion 0- to 6-in. Layer	Class II: Average Accretion 6- to 12-in. Layer
Thailand	17	0.47	0.20	17	0.64	0.59
United States	75	0.46	0.21	54	0.70	0.58
Alaska	10	0.56	0.20	--	--	--
Puerto Rico	8	0.62	0.23	8	0.74	0.74
Hawaii	15	0.45	0.26	12	0.64	0.68

Comparison of selected Thailand and western hemisphere PD sites

81. Three Thailand sites differing in soil texture were compared to selected sites in the western hemisphere with somewhat similar soil and site conditions for field-maximum and field-minimum moisture contents and depletion loss values as follows:

Soil Texture	Moisture Content in. Water/6 in. of Soil: 0- to 6-in. Layer	6- to 12-in. Layer	0- to 6-in. Layer	6- to 12-in. Layer
Sandy:	PD 38, East Texas		PD 246, Khon Kaen	
Field maximum	1.41	1.56	1.43	1.43
Field minimum	0.18	0.15	0.17	0.23
Depletion loss				
10-day	0.81	0.88	0.92	0.61
20-day	1.11	1.18	1.19	1.15
Silty:	PD 2, Vicksburg		PD 241, Chiang Mai	
Field maximum	2.52	2.43	2.38	2.05
Field minimum	0.75	0.91	0.62	0.61
Depletion loss				
10-day	0.82	0.65	0.52	0.48
20-day	1.62	1.18	1.58	1.06
Clayey:	PD 183, Puerto Rico		PD 259, Chanthaburi	
Field maximum	2.80	2.73	2.52	2.59
Field minimum	1.22	1.57	1.22	1.51
Depletion loss				
10-day	0.70	0.25	0.75	0.38
20-day	1.22	0.81	1.25	0.67

The paired sites of similar soil and site conditions have comparable ranges in natural moisture contents and reasonable agreements in depletion loss values. The Thailand results not only show that the prediction method is applicable, but also show that the values of derived prediction relations have magnitudes similar to those of comparable soils in other areas. Application of soil moisture values by analogy need not be limited to a test locality but may be projected to a remote area, provided similarity exists in soil, site, and seasonal conditions that govern the moisture characteristics.

PART VI: APPLICATION OF TRAFFICABILITY PREDICTION SYSTEM

82. Estimating soil trafficability has a direct application in the vital problem of determining ground mobility. Although estimates of soil trafficability cannot be expected to define trafficability with the accuracy obtainable by ground reconnaissance parties using instruments, it appears probable that trafficability can be predicted with sufficient accuracy to provide the strategic military planner with better guidance than has previously been available. Trafficability prediction methods have been based on the premise that the trafficability of a given soil is affected primarily by changes in its moisture content. If the characteristics of a soil (i.e. its shear strength as a function of moisture content) are known and its water content can be estimated, it is then possible to estimate the strength of the soil with reasonable accuracy. This section of the report describes how the trafficability prediction system can be applied by correlating Thailand soil moisture data to South Vietnam conditions and by using moisture records of a selected Thailand PD site for estimating soil strength (trafficability in terms of RCI); it also discusses how average prediction relations can be developed for an area that is not necessarily analogous to any specific test site.

Estimating Soil Moisture Conditions of South Vietnam

83. During the course of this study, the Advanced Research Projects Agency, Department of Defense, requested information on soil moisture conditions in South Vietnam. A summarization of Thailand soil moisture data was correlated to South Vietnam conditions, considering pedological soil classes and rainfall conditions of the two countries. A map was made presenting the expected moisture conditions in the 6- to 12-in. layer of South Vietnam soils by broad classes of soils and seasons. The report of the study and the map are presented in Appendix B. Maps can be prepared similarly for soil moisture and soil strength in other countries of the region if sufficient soil and weather data are available.

Estimating Soil Strength from Soil Moisture Records

84. Soil strength for trafficability purposes can be estimated from soil moisture records. To demonstrate the application a conversion of moisture to strength was made using the moisture record of site PD 241 (Vol II, table II-2) and the RCI-MC specific equation (equation constants in table 5). The estimated strength reccrd showed the seasonal difference of the monsoon climate. During the dry seasons of this record, soil strength was continuously greater than 150 RCI, and during the wet seasons was generally in the 60 to 100 RCI range. The wet season occurred in 1964 from 27 July to 27 October and in 1965 from 2 June to the end of the record on 17 October, 2 months longer than the previous year. Strength conditions varied during the wet seasons, reflecting the amount and distribution of rainfall plus water table effects. The depletion curve values for site PD 241, table 7, show that the expected loss from the 6- to 12-in. layer is 0.05 in. of water per day near the field maximum, which loss is equivalent to a strength increase of 10 to 20 RCI units. More than half of the days during the monsoon season are depletion days which occasionally occur as dry spells of 5 days and more. Therefore, fluctuation in strength which may range to 100 units can be expected in the wet season. On the other hand, a rainy spell with significant rain on consecutive days, or presence of a low-responsive water table near the soil surface, can stabilize the strength condition at a low level. On four occasions during the 1964 wet season the soil dried and the strength rose to 150 RCI for 2- or 3-day durations. During the last half of this season the strength remained near 60 RCI with five occurrences of lower strength. In the 1965 wet season the strength was more consistently in the 60 to 100 RCI range. However, the strength increased past 150 RCI for a 2-week period in mid-July, and on five occasions the strength dropped below 60 RCI for a day or more. This example demonstrates considerable differences in strength conditions between the 2 years, in time of inception, in duration, and in fluctuations in the strength range critical to performance of most vehicles.

85. The example utilized the record of moisture measurements and the specific strength-moisture relations. The procedure can be extended over

a time period of many years by using the specific moisture-prediction relations and the rainfall record to predict a moisture record and by converting this record to strength using the strength-moisture relation. The daily strength values over the long time period can be summarized on an annual basis to give averages and deviations of inception dates and durations of specified low strength values, frequency and duration of high strength during the low strength period, and occurrence of low strength during the dry season. The results would be applicable to analogous soil, site, and weather conditions elsewhere.

Average Prediction Relations and Their Use

86. Average prediction relations can be developed from many sets of specific relations by correlation with the soil and site factors that govern the magnitudes and rates of change of the prediction relations. With average relations and knowledge of the necessary soil and site factors, a set of prediction relations can be estimated for use in an area that is not necessarily analogous to any specific test site. The set would represent an interpolation among conditions of various sites. Tentative average moisture-prediction relations were developed and tested in the United States with fair accuracy (reference 5), but it was found that improvements were needed in the average relations to allow for water table effects and for soils high in clay or organic content. The average relations were applied to Puerto Rico sites with poor accuracy,[6] due in part to the large number of clay soils included in the study, and also to depletion differences and other factors. The United States average prediction relations were not tested in the Thailand study due to time limitations and to the recognition that the averages need improvement to apply to a greater range of natural conditions. The existence of similarities in specific prediction relations between Thailand and the west (paragraphs 80 and 81) indicates that average relations can be derived that are applicable to Thailand or elsewhere. With average relations, moisture predictions and strength interpretations could be made for the Thailand survey sites as discussed for the PD sites in the preceding section, thus

providing a broader array of daily strength records for analogic interpretations of untested areas. Pending development of average strength-moisture relations, strength estimations could be made directly for untested areas provided information is available on the soil and site factors necessary to adjust and select suitable average relations.

PART VII: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

87. Soil moisture, soil strength, and other relevant data were collected to depict changing conditions of representative environments for application to problems of soil trafficability throughout Thailand and elsewhere in Southeast Asia. Based on the data analysis performed herein, it was concluded that:

- a. Specific soil strength-moisture relations derived for 75 individual sites were mostly good for CI, with 63 sites having significant relations (table 3); poor for RI, with 27 sites having significant relations (table 4); and generally good for RCI, with 55 sites having significant relations (table 5). The variability and trend of the relations were similar to those found in the United States.[13]
- b. RCI changed about 20 units per 1% change in MC at the 100 RCI level. The rate of RCI change varied by moisture level and soil material (paragraph 50).
- c. For the sites tested, 75% had soil strengths at times in the 61 to 160 RCI range; and 36% had critically low strength (60 RCI or less) at times (paragraph 48).
- d. The soils with the lowest minimum estimated strengths (RCI), include: soils high in silt, 30% to 70% (paragraphs 54 and 55); soils with moderate clay content, 10% to 26% (paragraphs 54 and 55); soils with low plasticity, 1% to 50% liquid limit and 1% to 22% plasticity index (paragraph 56); certain pedological great soil groups, namely: Gray Podzolic, Noncalcic Brown, Humic Gley, Low-Humic Gley, and certain Alluvial soils (paragraph 59); soils with water tables near the surface (paragraph 61); soils on middle and lower terraces, depressions, and floodplains (paragraph 62); and soils in rice culture and certain grazing lands (paragraph 63). Many of the low strength categories had exceptional soils that remained firm. Often various categories of low strength were associated; for example, many rice paddies were located on the lower terraces with silty, low plasticity, Low-Humic Gley soils subject to water tables. On the other hand, characteristics were not always associated as expected. For instance, some sites in Pran Buri and western Chanthaburi areas, which had the lowest measured strengths in the study, did not have water tables near the ground surface (paragraph 61).
- e. The patterns of daily moisture change in Thailand were

similar to those found in the United States upon which the soil moisture-prediction method was developed (plate 6).

f. Specific soil moisture-prediction relations were derived for 17 Thailand sites and tested for accuracy by predicting moisture content for the period of record. Prediction accuracy of drained sites, with an average deviation between predicted and measured values of 0.11 in. in the 6- to 12-in. layer, compared favorably with the 0.08-in. deviation found in the United States. The prediction method is as applicable to Southeast Asia conditions as to the United States (paragraph 78).

g. A winter seasonal effect with reduced depletion rates was found in Thailand, which differs from other tropical studies under insular climates for which one set of depletion curves was applied throughout the year (paragraph 72).

h. Prediction accuracy was poor for many sites influenced by water tables, emphasizing the need for adjustment or modifications in the specific relations to improve predictions at the times most critical to trafficability (paragraph 77).

i. The similarities found in prediction relations, both wetting and drying, between Thailand and the western hemisphere indicate that average prediction relations can be derived that are applicable to Thailand (paragraphs 80 and 81). Average relations from which conditions between test sites can be interpolated would have broader application than specific relations for Thailand and elsewhere.

j. An example of estimating strength using specific strength-moisture relations and a measured moisture record demonstrated the utility of the method for ascertaining times during which low strength occurs. A meaningful strength increment of 20 to 40 RCI units corresponded to a moisture difference of 0.10 in. in a 6-in. soil layer, within the accuracy of moisture measurement. In applying the moisture-prediction method and average relations, the accuracy of values will be less, and a meaningful strength increment will be increased (paragraph 84).

k. The application of the data was demonstrated in the derivation of a general soil moisture map for South Vietnam (Appendix B).

Recommendations

88. It is recommended that analyses and studies be continued in order to improve accuracy and broaden the application of the trafficability

prediction method. Major areas of effort should include:

a. Water table influence. The water table influence is the greatest source of error in predictions using specifically derived relations. Modifications in the prediction method are needed to account for time of occurrence and duration of the water table effect. The capability of identifying soils and sites subject to water table influence is also needed.

b. Average moisture-prediction relations. The tentative average relations were derived from limited sites in the United States. New average relations are needed to encompass a broader range of natural conditions, including Thailand and other tropical sites. The new average relations should incorporate means of accounting for the water table influence.

c. Average strength-moisture relations. The derivation of average strength-moisture relations is needed in the trafficability prediction method for application to problems of strength change with time in areas not strictly analogous to the test sites.

[See also PA 29,764 (Volume II).
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Table 1

Location and Description of Test Sites

Site No.	Nearest Weather Station	Location of Test Site Lat	Location of Test Site Long.	Elevation ft msl	Eng* Conf Landform	Topography Aspect	Topography Position**	Slope %	Drainage Surface	Drainage Internal	WI	Vegetation	Land Use
						Chiang Mai							
PD 241	Site gage	18°54'15"	99°00'56"	1030	IIC1	Level	T - Flat	Level	Poor	Poor	4	Herbaceous	Lawn
PD 242	Site gage	18°54'20"	99°01'08"	1060	IVC3	Southwest	U - Slope	4	Good	Medium	3	Herbaceous	Cultivated (idle)
PD 243	Site gage	18°55'07"	98°59'49"	1020	IIC1	Level	T - Flat	Level	Poor	Poor	4	Herbaceous	Lawn
TS 1	Chiang Mai Irr Hdqrs	18°46'39"	99°00'43"	1010	IIB2	Level	B - Flat	Level	Poor	Poor	2	Herbaceous	Lawn
TS 2	Chiang Mai Irr Hdqrs	18°46'52"	99°00'58"	1000	IIC1	Level	T - Flat	Level	Poor	Poor	2	Herbaceous	Lawn
TS 3	Doi Suthep Forestry Sta	18°48'21"	98°55'13"	3625	IVB2	Southeast	U - Upper slope	21	Good	Good	2	Hardwood forest	Undisturbed
TS 4	San Pa Tong Rice Exp Sta	18°37'16"	98°54'05"	1025	IIB1	Level	B - Depression	Level†	Poor	Poor	4	Herbaceous	Cultivated
TS 5	Chom Thong	18°27'49"	98°40'55"	1050	IIB1	Level	B - Flat	Level	Medium	Poor	3	Hardwood forest	Undisturbed
TS 6	Chom Thong	18°28'55"	98°40'19"	1043	IIC1	Southwest	T - Slope	4†	Poor	Poor	4	Herbaceous	Cultivated
TS 7	Chom Thong	18°29'33"	98°40'30"	1033	IIB1	Level	B - Flat	Level†	Poor	Poor	3	Herbaceous	Cultivated
TS 19B	Doi Saket	18°52'25"	99°09'23"	1075	IVC3	Level	U - Flat	Level	Medium	Medium	3	Hardwood forest	Undisturbed
TS 19C	Doi Saket	18°52'23"	99°09'14"	1072	IIC1	Level	T - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated
TS 19E	Doi Saket	18°52'08"	99°09'10"	1082	IVC3	Northeast	U - Lower slope	3	Good	Medium	2	Herbaceous, trees	Cultivated
						Khon Kaen							
PD 246	Site gage	16°20'20"	102°48'56"	548	IVC3	Level	U - Flat	Level	Poor	Good	2	Herbaceous	Lawn
PD 247	Site gage	16°20'26"	102°48'56"	538	IIC1	Level	T - Depression	Level	Poor	Poor	4	Herbaceous	Grazed
PD 248	Site gage	16°20'44"	102°48'40"	525	IIC1	Level	T - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated
PD 249	Site 248 gage	16°20'53"	102°48'25"	489	IIC1	East	T - Slope	3†	Poor	Poor	4	Herbaceous	Cultivated
TS 9	Seed Propagation Sta	16°28'57"	102°50'07"	607	IIC1	Level	U - Flat	Level	Medium	Medium	3	Herbaceous	Cultivated
TS 10	Seed Propagation Sta	16°28'44"	102°50'04"	646	IVC3	North	U - Slope	3	Good	Good	2	Herbaceous	Cultivated
TS 11	Khon Kaen	16°26'33"	102°48'22"	518	IIC1	Level	T - Flat	Level	Poor	Poor	4	Bare	Undisturbed
TS 12	Site 248 gage	16°21'37"	102°48'23"	492	IIB1	Level	B - Flat	Level	Medium	Poor	2	Herbaceous	Grazed
TS 13	Site 248 gage	16°21'04"	102°48'27"	489	IIB2	Level	B - Flat	Level	Medium	Poor	2	Herbaceous	Grazed
TS 14	Site 248 gage	16°20'50"	102°48'30"	482	IIB1	Level	B - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated
TS 56A	Khon Kaen	16°25'40"	102°53'30"	490	IIC1	Level	T - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated
TS 56B	Khon Kaen	16°25'40"	102°53'26"	491	IIC1	Level	T - Flat	Level†	Poor	Poor	4	Herbaceous	Lawn
TS 56D	Khon Kaen	16°25'36"	102°53'22"	490	IIC1	Level	T - Flat	Level	Poor	Poor	4	Herbaceous	Cultivated
						Nakhon Sawan							
PD 251	Site gage	15°40'06"	100°08'00"	110	IVC3	Level	U - Flat	Level	Medium	Good	2	Herbaceous	Lawn
TS 15	Wat Bowamprachasak	15°47'51"	99°57'30"	130	IIC1	Level	T - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated (idle)
TS 16	Nakhon Sawan Airport	15°42'15"	100°05'35"	80	IIB1	Level	B - Flat	Level	Poor	Poor	4	Herbaceous	Cultivated
TS 17	Krok Phra	15°36'00"	100°07'27"	115	IIB1	Level	B - Flat	Level	Medium	Medium	3	Herbaceous	Cultivated
TS 18	Krok Phra	15°35'29"	100°07'33"	98	IIC1	Level	T - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated
TS 19	Phayuhakiri	15°28'00"	100°10'04"	115	IIC1	Level	T - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated
TS 20	Khao Bokaeo Settlement	15°28'03"	100°14'13"	295	IVA1	Southwest	U - Lower slope	3	Good	Good	2	Herbaceous	Cultivated (idle)

(Continued)

* Explained in reference 4.
** U = upland, B = bottomland, T = terrace.
† Artificially leveled and/or diked.

Table 1 (Continued)

Site No.	Nearest Weather Station	Location of Test Site Lat	Location of Test Site Long.	Elevation ft msl	Eng Conf Landform	Topography Aspect	Topography Position	Slope %	Drainage Surface	Drainage Internal	WI	Vegetation	Land Use
						Lop Buri							
PD 252	Site gage	14°43'36"	100°47'57"	187	IIB1	Level	B - Depression	Level	Poor	Poor	4	Row crop	Cultivated
PD 253	Site gage	14°43'18"	100°48'19"	207	IVA4	Level	U - Lower slope	Level	Medium	Medium	3	Herbaceous	Lawn
PD 254	Site gage	14°43'27"	100°48'45"	279	IVA4	East	U - Lower slope	6	Good	Good	2	Row crop	Cultivated
PD 255	Site gage	14°36'16"	101°03'16"	131	IIB1	Level	B - Flat	Level	Poor	Poor	4	Herbaceous	Grazed
PD 256	Site gage	14°36'40"	101°03'40"	148	IVA4	Level	U - Flat	Level	Medium	Poor	4	Herbaceous	Grazed
TS 21	Koke Katheim Art. School	14°53'27"	100°38'46"	95	IVA1	Level	U - Flat	Level	Poor	Poor	4	Herbaceous	Cultivated (idle)
TS 22	Koke Katheim Art. School	14°54'03"	100°40'03"	89	IIB1	Level	B - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated (idle)
TS 23	Koke Katheim Art. School	14°54'27"	100°40'51"	112	IIB1	Level	B - Flat	Level	Poor	Poor	4	Herbaceous	Cultivated (idle)
TS 24	Koke Katheim Art. School	14°54'36"	100°42'16"	131	IVB3	Southeast	U - Lower slope	3	Good	Medium	4	Brush	Undisturbed
TS 25	Sara Buri	14°30'03"	100°55'18"	46	IIC1	Level	T - Flat	Level†	Poor	Poor	2	Herbaceous	Cultivated
TS 25A	Sara Buri	14°28'36"	100°56'02"	59	IIC1	Level	T - Flat	Level†	Poor	Poor	3	Herbaceous	Cultivated
TS 25B	Sara Buri	14°28'42"	100°56'07"	57	IIB1	Level	B - Flat	Level	Poor	Poor	4	Herbaceous	Grazed
TS 26	Wang Noi	14°15'15"	100°46'21"	7	IIC3	Level	B - Flat	Level	Poor	Poor	4	Herbaceous	Cultivated
						Bangkok							
PD 244	Site gage	13°40'00"	100°36'33"	5	IIC3	Level	B - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated (idle)
PD 245	Bang Khen (Kasetsart)	13°51'08"	100°35'00"	5	IIB3	Level	B - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated (idle)
TS 8	--	13°46'17"	100°28'25"	5	IIB3	Level	B - Flat	Level	Good	Poor	4	Herbaceous, trees	Cultivated
						Pran Buri							
PD 257	Site gage	12°34'34"	99°57'25"	23	IIE4	Level	B - Flat	Level	Poor	Poor	2	Herbaceous	Lawn
TS 29	Khao Tao Irrigation Sta	12°27'37"	99°58'39"	13	IIC3	Level	T - Flat	Level	Poor	Poor	4	Herbaceous	Undisturbed
TS 30	Khao Tao Irrigation Sta	12°27'27"	99°58'12"	49	IVC3	East	U - Slope	3	Good	Good	2	Herbaceous, trees	Cultivated
TS 31	Pran Buri Sugar Co. Farm 2	12°25'17"	99°52'31"	26	IIC1	Level	U - Flat	Level	Poor	Poor	2	Herbaceous	Undisturbed
TS 32	Pran Buri Sugar Co. Farm 2	12°25'09"	99°52'09"	30	IVC3	Level	U - Flat	Level	Medium	Good	2	Herbaceous	Cultivated (idle)
TS 33	Pran Buri Sugar Co. Farm 2	12°25'10"	99°51'04"	26	IIC1	Level	U - Flat	Level	Medium	Medium	2	Brush	Undisturbed
TS 34	Pran Buri Sugar Co. Factory	12°22'25"	99°53'23"	30	IIC1	Level	U - Flat	Level	Medium	Poor	2	Row crop	Cultivated
						Chanthaburi							
PD 258	Site gage	12°36'40"	102°06'24"	33	IVA2	East	U - Upper slope	3	Good	Good	2	Herbaceous, brush	Lawn
PD 259	Site gage	12°35'14"	102°03'33"	69	IVB1	Southeast	U - Upper slope	6	Good	Good	2	Herbaceous	Cultivated (idle)
TS 35	Sattahip Navy Base	12°41'00"	100°53'46"	33	IVC3	Level	U - Flat	Level	Medium	Good	2	Herbaceous, trees	Cultivated
TS 36	Sattahip Navy Base	12°40'00"	100°53'50"	66	IVA2	East	U - Lower slope	4	Good	Good	2	Herbaceous, trees	Cultivated
TS 37	Huat Pong Upland Exp Sta	12°44'01"	101°08'12"	115	IVC3	Level	U - Flat	Level	Medium	Medium	2	Herbaceous, trees	Cultivated
TS 38	Rayong	12°41'51"	101°11'51"	26	IIB1	Level	B - Flat	Level	Poor	Poor	4	Herbaceous	Grazed
TS 39	Rayong	12°44'24"	101°17'18"	23	IIB1	Level	B - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated
TS 40	Chanthaburi	12°36'54"	102°07'43"	13	IIC1	Level	T - Flat	Level†	Poor	Poor	4	Herbaceous	Lawn
TS 41	Phriew Upland Exp Sta	12°30'30"	102°10'27"	66	IVC3	Level	U - Flat	Level	Medium	Medium	4	Herbaceous, trees	Cultivated
TS 42	Phriew Upland Exp Sta	12°30'39"	102°10'44"	105	IVB3	Northwest	U - Lower slope	3	Good	Good	2	Herbaceous, trees	Cultivated

(Continued)

† Artificially leveled and/or diked.

Table 1 (Concluded)

Site No.	Nearest Weather Station	Location of Test Site Lat	Location of Test Site Long.	Elevation ft msl	Eng Conf Landform	Topography Aspect	Topography Position	Slope %	Drainage Surface	Drainage Internal	WI	Vegetation	Land Use
						Hat Yai							
PD 260	Site gage	7°00'54"	100°30'00"	49	IVC3	Level	U - Flat	Level	Good	Good	2	Herbaceous, trees	Cultivated
TS 43	Rattaphum Irr Sta	7°07'21"	100°13'37"	115	IIC1	Level	U - Flat	Level	Medium	Medium	3	Herbaceous, trees	Cultivated
TS 44	Rattaphum Forestry Sta	7°01'10"	100°17'42"	131	IVA5	West	U - Lower slope	5	Good	Good	2	Hardwood forest	Undisturbed
TS 45	Kho Hong Rubber Exp Sta	7°00'42"	100°30'33"	66	IVA3	West	U - Lower slope	8	Good	Medium	2	Herbaceous, trees	Cultivated
TS 46	Kho Hong Rubber Exp Sta	7°01'08"	100°30'09"	43	IIB1	Level	B - Flat	Level	Poor	Poor	4	Herbaceous	Cultivated (idle)
TS 47	Hat Yai	7°04'02"	100°32'27"	69	IVB2	East	U - Lower slope	3	Good	Good	2	Herbaceous, trees	Cultivated
TS 48	Hat Yai	7°04'02"	100°32'42"	43	IIC1	Level	T - Flat	Level†	Poor	Poor	4	Herbaceous	Cultivated
TS 49	Songkhla Airport	7°10'00"	100°37'00"	10	IIC3	Level	B - Flat	Level	Poor	Poor	4	Herbaceous	Grazed
TS 50	Songkhla Airport	7°11'10"	100°36'10"	7	IIE4	Level	B - Flat	Level	Medium	Medium	4	Herbaceous	Undisturbed

† Artificially leveled and/or diked.

Table 2

Classification and Properties of Soils at Test Sites

Site No.	Great Soil Group	Soil Series	Soil Depth in.	Tex Class.	USDA Gravel Volume %	USDA Mech Analysis by wt, % Sand	Silt	Clay	USCS Type	Gravel by wt %	Fines by wt %	Organic Matter by wt %	Atterberg Limits, % LL	PL	PI	Bulk Density g/cc	Soil Moisture, % Total Pore Sat'n	At Moisture Tensions 0.06 atm	3 atm	15 atm	Specific Gravity	pH	EC at 25 C*
									Chiang Mai														
PD 241	Low-Humic Gley	Lampang	0-6	L	0	35	49	16	CL-ML	0	77	2.87	26	19	7	1.28	39.7	31.4	15.4	8.3	2.60**	4.6	1.2
			6-12	L	3	31	49	20	CL-ML	0	75	0.95	25	18	7	1.46	31.0	23.3	14.4	7.8	2.67	5.0	0.1
PD 242	Red-Yellow Podzolic	Mae Rim (P)	0-6	SL	0	73	20	7	SM	0	44	0.78	16	16	0	1.40	33.7	20.8	4.2	2.7	2.65**	5.5	0.2
			6-12	SL	0	69	24	7	SM	0	47	0.55	14	14	0	1.48	29.8	21.3	4.3	2.5	2.65**	5.6	0.1
PD 243	Low-Humic Gley	Lampang	0-6	L	0	39	45	16	CL	0	72	1.55	24	16	8	1.53	26.9	21.0	12.0	5.5	2.60**	4.4	0.5
			6-12	L	0	42	45	13	CL-ML	0	69	0.62	18	13	5	1.69	21.7	16.3	11.3	5.5	2.67**	5.1	0.03
TS 1	Alluvial	Tha Muang	0-6	L	0	39	42	19	ML	0	77	2.75	34	24	10	1.38	34.6	26.9	16.1	11.6	2.64**	6.1	0.2
			6-12	L	0	38	44	18	CL	0	81	2.08	30	20	10	1.43	32.0	29.2	16.2	12.3	2.64**	6.5	0.2
TS 2	Low-Humic Gley	Hang Dong	0-6	CL	0	22	50	28	ML	0	86	3.13	49	29	20	1.18	47.5	34.6	23.4	17.6	2.69**	6.5	0.5
		Low phase	6-12	CL	0	20	50	30	CL	0	86	2.23	43	25	18	1.20	46.2	36.7	22.3	17.6	2.69	6.5	0.3
TS 3	Red-Yellow Podzolic to	Lat Ya (P)	0-6	CL	0	39	33	28	MH	0	73	5.74	65	45	20	0.80	85.4	47.9	33.4	26.0	2.59	4.0	0.8
	Reddish-Brown Lateritic		6-12	CL	0	37	27	36	MH	0	70	3.27	56	33	23	0.95	66.7	39.2	27.1	23.3	2.59	4.5	0.2
TS 4	Humic Gley	Mae Khan	0-6	L	0	46	32	22	CL	0	61	2.08	35	18	17	1.50†	32.0†	28.4	17.4	14.9	2.63	6.9	0.8
			6-12	CL	0	26	40	34	CL	0	79	1.65	38	20	18	1.61†	28.0†	24.5	20.6	16.7	2.63	7.1	0.4
TS 5	Alluvial	Local	0-6	SL	3	67	22	11	SM	2	41	0.95	17	17	0	1.46	30.8	19.3	7.0	5.5	2.65**	8.4	0.4
		alluvium	6-12	SL	3	54	27	19	CL-ML	1	56	0.87	22	16	6	1.43	32.2	19.9	9.1	7.1	2.65**	8.1	0.4
TS 6	Alluvial	Local	0-6	L	4	31	47	22	CL	2	72	1.45	42	21	21	1.36	36.2	30.3	21.0	14.4	2.68**	7.8	0.8
		alluvium	6-12	L	3	32	50	18	CL	0	79	0.86	30	17	13	1.41	33.6	22.0	15.1	10.8	2.68**	8.2	0.5
TS 7	Alluvial	NC	0-6	LS	0	85	9	6	SM	0	21	0.46	--	NP	NP	1.18	47.0	22.2	4.7	3.4	2.65**	5.3	0.3
			6-12	LS	0	86	9	5	SM	0	17	0.32	--	NP	NP	1.36	35.8	15.5	3.4	2.4	2.65**	5.1	0.1
TS 19B	Gray Podzolic	San Pa Tong	0-6	SL	0	71	22	7	SM	0	43	0.70	--	NP	NP	1.49	29.5	18.7	4.7	3.4	2.66**	5.2	0.4
			6-12	LS	0	79	16	5	SM	0	32	1.04	--	NP	NP	1.54	26.9	16.6	3.7	2.2	2.63	4.9	0.1
TS 19C	Low-Humic Gley	Lampang	0-6	SL	0	71	21	8	SM	0	36	0.86	--	NP	NP	1.38	34.9	--	9.1	4.0	2.66**	5.2	0.1
			6-12	SL	0	69	13	18	SC	0	37	0.39	24	13	11	1.60	24.5	--	12.8	8.1	2.63**	5.2	0.1
TS 19E	Red-Yellow Podzolic	Inclusion in	0-6	LS	0	77	20	3	SM	0	32	0.46	--	NP	NP	1.40	33.8	14.9	2.5	1.7	2.66**	5.3	0.2
		San Pa Tong	6-12	LS	0	75	21	4	SM	0	33	0.78	--	NP	NP	1.51	28.3	12.5	2.0	1.5	2.64	5.6	0.03
									Khon Kaen														
PD 246	Gray Podzolic	Yang Talat (P)	0-6	LS	0	78	15	7	SM	0	33	0.95	16	16	0	1.61	24.3	15.3	3.7	2.5	2.65**	5.1	0.6
		to Korat	6-12	SL	0	77	15	8	SM	0	37	0.62	14	14	0	1.63	23.6	14.3	3.9	3.0	2.65**	5.3	0.2
PD 247	Low-Humic Gley	Roi Et	0-6	SL	0	70	19	11	SM	0	43	1.05	17	17	0	1.51	27.9	18.5	7.2	4.7	2.61	4.5	0.5
		depression	6-12	SL	0	62	26	12	SM	0	48	0.95	14	14	0	1.54	26.6	17.7	10.9	4.8	2.61	5.3	0.2
PD 248	Low-Humic Gley	Roi Et	0-6	SL	0	76	17	7	SM	0	38	0.78	16	16	0	1.44	31.7	17.8	5.1	3.2	2.65**	5.0	0.3
		sandy phase	6-12	SL	0	75	17	8	SM	0	39	0.46	14	14	0	1.50	28.9	15.6	4.4	2.8	2.65**	5.7	0.1
PD 249	Solodized-Solonetz	NC	0-6	SL	0	61	27	12	ML	0	57	0.78	20	18	2	1.44	31.2	23.9	9.4	6.5	2.62	5.4	0.3
			6-12	SL	0	61	23	16	ML	0	57	0.46	18	17	1	1.45	31.1	25.1	10.2	6.9	2.64	6.5	0.3

(Continued)

Note: P, provisional name; NC, not classified; NP, nonplastic.
* Electrical conductivity, millimhos/cm.
** Estimated value.
† Bulk density questionable, total pore saturation from gravimetric sampling.

Table 2 (Continued)

Site No.	Great Soil Group	Soil Series	Soil Depth in.	USDA Tex Class.	USDA Gravel Volume %	USDA Mech Analysis by wt, % Sand	Silt	Clay	USCS Type	USCS Gravel by wt %	USCS Fines by wt %	Organic Matter by wt %	Atterberg Limits, % LL	PL	PI	Bulk Density g/cc	Soil Moisture, % Total Pore Sat'n	At Moisture Tensions 0.06 atm	3 atm	15 atm	Specific Gravity	pH	EC at 25 C
									Khon Kaen (Continued)														
TS 9	Regosolic Gray	Yang	0-6	LS	0	75	20	5	SM	0	32	0.86	--	NP	NP	1.59	25.2	14.0	3.4	2.3	2.65**	5.8	0.2
	Podzolic	Talat (P)	6-12	LS	0	81	14	5	SM	0	31	0.62	--	NP	NP	1.63	23.6	13.1	3.3	1.3	2.65**	6.0	0.1
TS 10	Red Latosol	Yasothon	0-6	SL	0	68	24	8	SM	0	43	0.78	17	15	2	1.53	27.3	16.2	4.6	3.8	2.63**	6.1	0.2
			6-12	SL	0	74	18	8	SM	0	39	0.62	--	NP	NP	1.54	26.9	16.5	4.0	3.1	2.63	6.2	0.1
TS 11	Low-Humic Gley	Udon	0-6	LS	0	82	13	5	SM	0	33	0.46	--	NP	NP	1.67	22.0	14.7	2.6	1.6	2.64**	7.7	20.3
	overwashed by 5-in. local alluvium		6-12	LS	0	77	20	3	SM	0	40	0.46	13	13	0	1.73	19.9	14.9	3.2	2.0	2.64	8.0	8.1
TS 12	Alluvial	Chiang Mai to	0-6	L	0	48	41	11	ML	0	71	0.86	27	22	5	1.26	42.1	25.8	10.5	6.5	2.68**	4.5	0.2
		Rat Buri	6-12	L	0	41	42	17	CL-ML	0	76	0.78	26	20	6	1.27	41.4	25.9	13.2	7.7	2.68**	4.8	0.2
TS 13	Alluvial	Chiang Mai	0-6	L	0	43	44	13	ML	0	80	1.65	30	23	7	1.50	29.3	23.0	11.8	8.2	2.68**	5.1	0.5
			6-12	L	0	43	43	14	CL-ML	0	80	0.78	25	19	6	1.46	31.2	23.5	12.0	8.0	2.68**	5.4	0.1
TS 14	Alluvial	Phimai	0-6	CL	0	26	46	28	CL	0	84	1.45	37	19	18	1.23	44.6	32.2	19.6	12.6	2.72**	4.8	0.2
			6-12	SiCL	0	13	51	36	CL	0	93	1.05	41	18	23	1.30	40.2	30.1	17.6	16.2	2.72**	5.2	0.2
TS 56A	Low-Humic Gley	Roi Et	0-6	L	0	43	34	23	CL	0	67	0.70	26	14	12	1.35	36.7	23.0	13.8	9.4	2.68**	5.1	0.2
			6-12	L	0	41	35	24	CL	0	68	0.92	32	17	15	1.50	29.3	20.4	16.8	13.0	2.68**	5.1	0.1
TS 56B	Low-Humic Gley	Roi Et	0-6	L	0	47	32	21	CL	0	66	0.62	26	15	11	1.57	26.4	21.1	11.9	8.6	2.68**	4.7	0.2
			6-12	L	0	41	35	24	CL	0	74	0.78	32	17	15	1.59	25.3	21.0	17.4	13.8	2.67**	5.5	0.1
TS 56D	Low-Humic Gley	Roi Et	0-6	L	0	45	38	17	CL	0	60	0.95	24	16	8	1.27	41.4	23.4	13.7	9.0	2.67**	5.6	0.1
			6-12	SCL	0	52	27	21	CL	0	64	0.62	27	17	10	1.27	41.3	22.7	11.5	8.9	2.67**	5.5	0.1
									Nakhon Sawan														
PD 251	Red-Brown Earth	Pak Chong	0-6	CL	0	25	44	31	CL	0	80	2.87	47	21	26	1.30	39.8	27.3	20.3	16.0	2.69**	6.0	0.1
			6-12	CL	0	25	40	35	CL	0	81	2.23	48	23	25	1.43	32.7	28.0	20.5	16.6	2.69	6.2	0.1
TS 15	Low-Humic Gley	Khrok	0-6	SiCL	0	20	48	32	CL	0	86	1.45	32	19	13	1.20	45.8	31.2	21.4	15.7	2.66**	5.6	0.1
		Phra (P)	6-12	SiC	0	11	41	48	CL	0	92	0.78	45	22	23	1.33	37.6	29.5	25.4	19.2	2.66	5.4	0.1
TS 16	Alluvial	Rat Buri	0-6	C	0	10	34	56	MH	0	96	2.35	64	32	32	1.04	59.1	38.6	29.0	24.4	2.70**	5.5	0.2
			6-12	C	0	5	33	62	CH	0	98	1.88	81	35	46	1.08	55.6	41.8	35.5	28.1	2.70	5.8	0.2
TS 17	Humic Gley to	Tha Tako to	0-6	L	0	44	34	22	CL	0	67	2.87	40	20	20	1.16	48.7	30.7	23.8	10.0	2.67	5.5	0.4
	Rendzina	Takli	6-12	L	0	41	33	26	CL	0	68	2.35	43	24	19	1.20	45.9	29.3	21.7	16.9	2.67**	5.5	0.2
TS 18	Low-Humic Gley	NC	0-6	SL	0	62	29	9	CL-ML	0	54	0.95	20	16	4	1.46	30.6	21.8	6.9	3.6	2.64**	6.0	0.2
			6-12	SL	0	59	27	14	CL-ML	0	53	0.62	19	14	5	1.38	34.6	20.9	9.6	6.4	2.64**	8.0	0.3
TS 19	Low-Humic Gley	Lampang	0-6	SL	0	59	28	13	SC	0	47	0.95	19	11	8	1.50	28.8	15.7	9.8	5.0	2.64**	5.8	0.3
			6-12	L	0	49	33	18	CL	0	57	0.70	24	12	12	1.67	22.0	16.8	13.0	9.0	2.64	6.0	0.1
TS 20	Red-Brown Earth	Pak Chong	0-6	SiC	2	17	43	40	CH	0	86	3.54	67	31	36	1.23	44.1	34.3	27.9	24.8	2.69**	8.2	0.5
			6-12	SiC	0	16	41	43	CH	0	89	2.75	68	29	39	1.19	46.8	35.5	28.4	25.8	2.69	8.4	0.5
									Lop Buri														
PD 252	Humic Gley	Tha Tako	0-6	SiCL	0	12	50	38	MH	0	95	3.27	78	45	33	1.01	61.8	41.2	35.6	35.2	2.69**	7.4	0.7
			6-12	SiC	0	11	47	42	CH	0	93	3.00	88	53	35	1.07	56.3	46.2	38.0	34.8	2.69	7.7	0.6

(Continued)

** Estimated value.

Table 2 (Continued)

Site No.	Great Soil Group	Soil Series	Soil Depth in.	USDA Tex Class.	USDA Gravel Volume %	USDA Mech Analysis by wt, % Sand	Silt	Clay	USCS Type	USCS Gravel by wt %	USCS Fines by wt %	USCS Organic Matter by wt %	Atterberg Limits, % LL	PL	PI	Bulk Density g/cc	Soil Moisture, % Total Pore Sat'n	At Moisture Tensions 0.06 atm	3 atm	15 atm	Specific Gravity	pH	EC at 25 C
									Lop Buri (Continued)														
PD 253	Red-Brown Earth to Brown Grumusol	Pak Chong	0-6	SiCL	0	12	49	39	CH	0	93	3.27	69	30	39	1.10	53.4	39.2	28.2	24.8	2.66**	6.6	0.4
			6-12	SiC	0	10	46	44	CH	0	96	2.75	72	43	39	1.13	50.9	39.0	29.2	24.8	2.66	6.3	0.2
PD 254	Red-Brown Earth	Pak Chong	0-6	C	2	12	39	49	MH	4	88	2.87	53	30	23	0.99	63.8	36.4	23.5	20.5	2.69**	5.7	0.3
			6-12	SiCL	0	14	51	35	CH	0	93	2.08	63	31	32	1.10	53.7	35.2	24.6	22.6	2.69	5.7	0.2
PD 255	Alluvial	Tha Tako	0-6	L	0	28	47	25	CL	0	83	1.65	36	18	18	1.25	42.0	29.2	16.3	12.6	2.63**	7.2	0.7
			6-12	L	0	30	46	24	CL	0	84	1.77	36	24	12	1.43	31.9	27.4	18.4	13.6	2.63	6.9	0.5
PD 256	Brown Grumusol to Alluvial	NC	0-6	CL	0	28	38	34	CH	0	83	2.23	58	25	33	1.34	37.7	33.0	21.8	18.1	2.71**	6.6	0.3
			6-12	CL	0	27	37	36	CH	0	84	1.77	62	36	36	1.38	35.6	28.6	23.1	19.1	2.71	6.5	0.2
TS 21	Grumusol	Lop Buri	0-6	CL	0	30	36	34	CH	0	78	1.25	53	18	35	1.57	26.6	25.7	22.9	19.8	2.70**	7.5	0.2
			6-12	CL	0	30	33	37	CH	0	79	1.05	55	18	37	1.62	26.0†	25.1	23.0	18.6	2.70	7.7	0.2
TS 22	Humic Gley	Tha Tako	0-6	CL	0	36	33	31	CL	0	74	1.05	49	20	29	1.43	32.7	29.8	23.0	16.9	2.68**	7.6	1.1
			6-12	CL	0	34	34	32	CL	0	78	1.05	47	17	30	1.47	31.0	28.2	24.4	16.6	2.70**	8.4	1.7
TS 23	Humic Gley	Tha Tako	0-6	CL	0	31	41	28	CL	0	79	1.55	42	19	23	1.30	39.6	31.6	20.9	16.7	2.68**	6.2	0.2
			6-12	CL	0	27	39	34	CH	0	83	1.15	51	18	33	1.51	30.4	30.4	22.7	17.7	2.68	6.9	0.2
TS 24	Red-Brown Earth	Pak Chong	0-6	L	0	43	32	25	CL	0	70	2.60	37	21	16	1.19	38.6	31.6	19.4	16.1	2.82**	6.3	0.1
			6-12	CL	2	41	28	31	CL	0	70	1.65	41	23	18	1.32	40.3	30.1	21.0	15.9	2.82	5.8	0.1
TS 25	Low-Humic Gley to Noncalcic Brown	Phet Buri	0-6	Si	0	9	84	7	ML	0	96	0.85	17	17	0	1.67	21.4	17.0	7.1	3.0	2.60**	4.9	0.1
			6-12	SiL	0	12	78	10	ML	0	94	0.62	16	16	0	1.78	17.7	14.6	7.0	3.8	2.60	6.0	0.1
TS 25A	Low-Humic Gley	Hin Kong	0-6	SiL	0	30	58	12	ML	0	78	1.05	27	22	5	1.47	29.5	24.7	11.2	7.0	2.60**	5.0	0.3
			6-12	SiL	0	29	51	20	ML	0	80	0.62	21	19	2	1.57	25.2	19.4	11.6	8.0	2.60**	5.6	0.1
TS 25B	Alluvial	Local alluvium	0-6	L	0	42	42	16	ML	0	66	1.05	29	22	7	1.50	28.9	23.0	15.6	8.9	2.65**	4.8	0.1
			6-12	L	0	43	41	16	SC-SM	0	44	0.62	23	17	6	1.65	22.8	19.6	13.2	8.4	2.65**	5.0	0.1
TS 26	Alluvial	Ongkarak	0-6	SiCL	0	16	49	35	MH	0	80	5.20	75	38	37	1.01	62.3	52.0	38.4	32.0	2.72**	4.1	4.5
			6-12	SiCL	0	13	49	38	CH	0	97	2.08	74	31	43	1.08	55.8	49.9	34.3	28.7	2.72**	3.9	3.0
									Bangkok														
PD 244	Alluvial	Bangkok	0-6	SiC	0	6	41	53	CH	0	99	1.98	72	27	45	1.15	49.7	48.0	33.1	25.7	2.68**	4.4	1.9
			6-12	C	0	6	37	57	CH	0	99	1.55	67	23	44	1.30	39.6	38.4	31.7	24.3	2.68	4.9	2.5
PD 245	Alluvial	Bang Khen	0-6	SiC	0	11	41	48	CH	0	98	3.00	67	29	38	1.29	40.2	38.0	34.7	26.5	2.68	4.9	2.9
			6-12	SiC	0	11	41	48	CH	0	98	1.65	66	27	39	1.34	37.3	37.3	32.3	25.8	2.68**	4.8	3.3
TS 8	Made Land	NC	0-6	SiC	0	13	43	44	CH	0	94	2.08	65	29	36	1.12	52.4	51.0	32.9	25.1	2.71**	6.7	0.7
			6-12	SiC	0	12	41	47	CH	0	94	1.45	66	29	37	1.14	50.8	49.9	33.7	22.3	2.71	5.8	0.4
									Pran Buri														
PD 257	Regosol	Hua Hin	0-6	SL	0	72	23	5	SM	0	37	0.70	--	NP	NP	1.39	34.2	15.7	3.5	3.0	2.65**	4.8	0.1
			6-12	SL	0	75	19	6	SM	0	33	0.55	--	NP	NP	1.47	30.3	15.8	4.4	2.9	2.65**	4.8	0.1
TS 29	Solodized-Solonetz	Nong Kae	0-6	SL	0	68	21	11	SM-SC	0	45	0.78	18	13	5	1.63	23.3	14.0	7.1	4.0	2.63	6.4	5.1
			6-12	SCL	0	54	17	29	SC	0	49	0.55	28	11	17	1.75	19.1	15.3	13.5	11.1	2.63**	7.3	7.8

(Continued)

** Estimated value.
† Bulk density questionable, total pore saturation from gravimetric sampling.

Table 2 (Continued)

Site No.	Great Soil Group	Soil Series	Soil Depth in.	USDA Tex. Class.	USDA Gravel Volume %	USDA Mech Analysis by wt, % Sand	Silt	Clay	USCS Type	USCS Gravel by wt %	USCS Fines by wt %	Organic Matter by wt %	Atterberg Limits, % LL	PL	PI	Bulk Density g/cc	Soil Moisture, % Total Pore Sat'n	At Moisture Tensions 0.06 atm	3 atm	15 atm	Specific Gravity	pH	EC at 25 C
Pran Buri (Continued)																							
TS 30	Red-Yellow Latosol	Siracha	0-6	SL	0	64	24	12	ML	0	51	1.05	18	15	3	1.29	40.1	19.6	7.4	5.1	2.67**	7.2	0.3
			6-12	SL	0	62	24	14	SM-SC	0	48	0.62	17	13	4	1.44	31.9	15.8	6.8	4.8	2.67	6.7	0.2
TS 31	Gray Podzolic to	Sattahip to	0-6	L	0	44	45	11	CL-ML	0	70	1.33	21	15	6	1.25	42.2	22.5	8.2	5.6	2.65**	5.3	0.4
	Low-Humic Gley	Chon Buri	6-12	L	0	38	44	18	CL-ML	0	73	0.78	20	13	7	1.39	30.6	20.2	10.7	7.7	2.65**	4.7	0.1
TS 32	Red-Yellow Latosol to	Siracha	0-6	L	0	48	40	12	CL-ML	0	64	0.95	18	14	4	1.27	41.0	21.7	8.0	4.5	2.65**	5.8	0.3
	Red-Yellow Podzolic		6-12	L	0	43	43	14	CL-ML	0	66	0.78	17	12	5	1.46	30.8	18.3	8.2	5.5	2.65**	5.6	0.2
TS 33	Noncalcic Brown	Pran Buri	0-6	SiL	0	27	55	18	CL	0	85	1.65	28	19	9	1.22	44.3	24.2	12.4	7.4	2.65**	6.9	0.4
			6-12	L	0	30	46	24	CL-ML	0	86	0.95	23	16	7	1.41	33.2	20.9	11.6	8.0	2.65**	7.1	0.2
TS 34	Noncalcic Brown	Pran Buri	0-6	L	0	39	43	18	CL	0	76	1.65	26	17	9	1.41	33.2	23.2	13.5	9.9	2.65**	6.8	0.7
			6-12	L	0	34	39	27	CL	0	80	1.15	27	14	13	1.62	24.0	19.4	14.6	11.4	2.65	6.3	0.3
Chanthaburi																							
PD 258	Reddish-Brown Lateritic	Trad	0-6	CL	0	25	36	39	MH	0	82	3.27	50	29	21	1.34	37.2	31.6	24.9	20.6	2.67**	4.4	0.4
			6-12	C	0	23	36	41	CH	0	83	1.98	50	28	22	1.30	39.5	30.3	24.3	20.9	2.67	4.6	0.1
PD 259	Red-Brown Latosol	Tha Mai	0-6	L	0	28	47	25	MH	0	90	3.00	53	40	13	0.87	80.2	53.7	32.8	26.7	2.88	4.3	0.4
			6-12	CL	0	24	47	29	MH	0	90	2.75	56	42	14	0.92	74.0	51.1	34.7	29.1	2.88	4.4	0.3
TS 35	Gray Podzolic	Sattahip	0-6	L	0	51	40	9	SM	0	48	0.78	16	14	2	1.57	26.0	15.0	5.7	3.5	2.65**	4.9	0.3
			6-12	SL	0	61	25	14	CL-ML	0	51	0.55	15	11	4	1.65	22.9	13.8	7.5	5.2	2.65**	5.0	0.1
TS 36	Reddish-Brown Lateritic	Li	0-6	L	0	47	35	18	CL	0	63	1.55	25	15	10	1.35	36.9	19.0	12.8	8.3	2.69**	5.6	0.3
			6-12	L	0	41	37	22	CL	0	67	0.78	27	16	11	1.33	38.0	20.6	13.9	9.7	2.69	5.7	0.2
TS 37	Gray Podzolic	Huai Pong	0-6	SCL	0	63	11	26	SC	0	41	1.45	25	13	12	1.33	36.9	16.1	12.3	9.4	2.61**	5.0	0.3
			6-12	SCL	0	61	9	30	SC	0	44	1.33	28	14	14	1.34	36.3	16.5	13.5	11.6	2.61	4.8	0.2
TS 38	Alluvial	NC	0-6	SiC	0	16	43	41	MH	0	93	11.5	107	75	32	0.71†	102.3†	95.8	61.4	44.3	2.29	4.0	1.4
			6-12	SiCL	0	19	46	35	MH	0	89	4.7	96	68	28	0.67†	125.8†	106.1	64.2	45.6	2.40	4.3	0.7
TS 39	Alluvial	Ban Kai	0-6	LS	0	76	20	4	SM	0	35	0.86	--	NP	NP	1.59	24.7	16.9	4.2	2.4	2.62**	4.3	0.4
			6-12	SL	0	68	19	13	SM	0	43	0.46	13	13	0	1.73	19.6	13.4	7.3	5.3	2.62	5.3	0.1
TS 40	Low-Humic Gley	Klaeng	0-6	SiC	C	7	52	41	MH	0	92	4.15	71	46	25	0.91	71.1	49.5	37.8	27.1	2.57**	4.2	0.8
			6-12	SiC	0	8	51	41	MH	0	92	3.62	66	38	28	0.98	63.2	49.3	35.8	27.7	2.57	4.5	0.4
TS 41	Gray Podzolic to	Huai Pong	0-6	SL	0	71	9	20	SC	0	34	1.77	29	20	9	1.38	34.0	19.4	13.2	9.6	2.60**	4.0	0.5
	Gray Hydromorphic		6-12	SCL	0	66	11	23	SC	0	39	1.25	25	14	11	1.38	34.0	17.4	13.9	11.4	2.60	4.5	0.2
TS 42	Red-Yellow Podzolic	NC	0-6	SCL	3	58	16	26	SC	0	43	3.41	43	25	18	1.11	51.8	24.5	17.0	13.5	2.61**	4.3	0.9
			6-12	SCL	3	57	14	29	SC	1	43	2.87	42	23	19	1.15	48.6	23.5	16.8	15.0	2.61	4.4	0.5
Hat Yai																							
PD 260	Red-Yellow Latosol	NC	0-6	SL	0	61	31	8	CL-ML	0	51	1.45	22	18	4	1.35	36.2	21.9	7.2	5.2	2.64**	4.1	0.9
			6-12	SL	0	65	22	13	CL-ML	0	51	0.78	19	15	4	1.60	24.6	18.0	8.8	5.7	2.64	4.2	0.3
TS 43	Gray Podzolic to	NC	0-6	SL	0	56	28	16	CL	0	58	2.23	33	22	11	1.54	27.2	21.4	15.0	9.4	2.65**	4.8	0.4
	Noncalcic Brown		6-12	SL	0	52	30	18	CL	0	59	1.15	31	20	11	1.55	26.8	21.8	15.8	10.3	2.65**	4.7	0.2
TS 44	Red-Yellow Podzolic	Tha Yang	0-6	SL	8	53	38	9	ML	6	55	1.77	21	18	3	1.73	24.0	16.6	13.9	6.4	2.96**	4.0	0.4
			6-12	L	34	50	34	16	GC	36	29	0.78	26	17	9	1.75	23.4	15.6	10.6	8.2	2.96	5.2	0.2

(Continued)

** Estimated value.
† Bulk density questionable, total pore saturation from gravimetric sampling.

Table 2 (Concluded)

Site No.	Great Soil Group	Soil Series	Soil Depth in.	USDA Tex. Class.	USDA Gravel Volume %	USDA Mech Analysis by wt, % Sand	Silt	Clay	USCS Type	USCS Gravel by wt %	USCS Fines by wt %	USCS Organic Matter by wt %	USCS Atterberg Limits, % LL	PL	PI	Bulk Density g/cc	Soil Moisture, % Total Pore Sat'n	At Moisture Tensions 0.06 atm	3 atm	15 atm	Specific Gravity	pH	EC at 25 C
									Hat Yai (Continued)														
TS 45	Red-Yellow Podzolic	Tha Yang	0-6	SL	5	58	25	17	SC	8	49	1.98	27	18	9	1.47	30.1	21.2	12.4	7.9	2.64**	3.8	0.6
			6-12	SCL	9	53	26	21	SC	2	46	1.65	29	18	11	1.67	22.0	16.0	12.0	9.5	2.64**	4.2	0.3
TS 46	Alluvial	Local	0-6	L	0	38	48	14	ML	0	74	2.35	34	24	10	1.35	36.1	33.4	17.9	10.7	2.63**	4.1	0.2
		alluvium	6-12	L	0	43	43	14	CL-ML	0	70	0.95	21	16	5	1.62	23.7	22.5	11.2	7.5	2.63	4.1	0.2
TS 47	Reddish-Brown	Khlong Chack	0-6	CL	0	35	38	27	MH	0	75	3.96	58	32	26	1.18	49.8	37.8	26.9	20.4	2.87**	4.5	0.4
	Lateritic	or Li	6-12	CL	9	33	32	35	MH	12	62	1.15	58	33	25	1.29	42.6	32.6	24.4	20.3	2.87	4.9	0.1
TS 48	Low-Humic Gley	Chon Buri	0-6	SiL	0	32	54	14	CL	0	79	1.33	23	15	8	1.39	34.5	24.3	11.6	6.7	2.67**	5.0	0.1
		(Prov)	6-12	L	0	29	47	24	CL	0	80	0.70	26	14	12	1.56	26.6	18.6	13.9	10.6	2.67	5.4	0.1
TS 49	Alluvial	Ongkarak	0-6	CL	0	25	47	28	MH	0	82	14.35	103	68	35	0.63	115.5	104.0	55.5	43.0	2.31	4.4	5.2
			6-12	C	0	19	40	41	MH	0	88	4.90	70	35	35	1.19†	75.1†	38.1	33.8	31.2	2.60**	4.4	3.4
TS 50	Ground-water Podzol	NC	0-6	S	0	95	4	1	SP-SM	0	7	2.75	--	NP	NP	1.32	36.9	16.9	3.9	3.0	2.57**	4.4	0.4
			6-12	S	0	93	4	3	SP-SM	0	10	3.54	--	NP	NP	1.42	31.5	18.8	6.5	4.0	2.57	4.8	0.2

** Estimated value.
† Bulk density questionable, total pore saturation from gravimetric sampling.

Table 3

Summary of CI Ranges and CI-MC Relations

Site No.	No. of Measurements	Range of CI	No. of Measurements Within CI Increments of <80	80-119	120-299	300-749	>749	Correlation Coefficient	Specific Equation Constants Intercept	Slope
					Chiang Mai Area					
PD 241	25(20)	87-750+	--	4	11	5	5	-0.80*	4.91	-2.04
PD 242	26(20)	104-750+	--	3	14	3	6	-0.91*	3.89	-1.56
PD 243	26(20)	121-750+	--	--	8	12	6	-0.57*	9.81	-6.22
TS 1	20(8)	419-750+	--	--	--	8	12	-0.69NS	7.40†	-3.78†
TS 2	24(18)	131-750+	--	--	11	7	6	-0.92*	6.37	-2.82
TS 3	17(17)	73-429	1	5	8	3	--	-0.90*	6.62	-3.02
TS 4	22(22)	102-642	--	5	13	4	--	-0.91*	7.11	-3.58
TS 5	21(13)	149-750+	--	--	9	4	8	-0.46NS	4.14†	-1.55†
TS 6	22(22)	69-542	1	8	10	3	--	-0.63*	6.64	-3.43
TS 7	12(12)	224-490	--	--	6	6	--	-0.88*	3.89	-0.99
TS 19B	9(9)	235-379	--	--	5	4	--	-0.90*	4.39	-1.66
TS 19C	10(10)	147-178	--	1	9	--	--	-0.49NS	4.92†	-2.15†
TS 19E	10(10)	125-300	--	--	9	1	--	-0.73*	3.41	-1.03
					Khon Kaen Area					
PD 246	19(14)	182-750+	--	--	9	5	5	-0.92*	3.19	-0.80
PD 247	16(13)	139-750+	--	1	4	8	3	-0.95*	4.89	-2.13
PD 248	18(17)	178-750+	--	--	2	15	1	-0.78*	4.47	-1.65
PD 249	16(11)	388-750+	--	--	--	11	5	-0.64**	3.47	-0.64
TS 9	18(18)	108-736	--	1	10	7	--	-0.86*	3.48	-1.17
TS 10	17(15)	87-750+	--	4	5	6	2	-0.97*	3.25	-1.10
TS 11	18(18)	184-583	--	-	4	14	--	-0.79*	6.74	-3.61
TS 12	17(9)	146-750+	--	-	6	3	8	-0.86*	4.24	-1.51
TS 13	18(10)	106-750+	--	2	5	3	8	-0.97*	4.26	-1.60
TS 14	15(11)	115-750+	--	1	5	5	4	-0.83*	6.89	-3.25
TS 56A	6(6)	172-413	--	--	4	2	--	-0.98*	5.21	-2.22
TS 56B	5(5)	101-176	--	2	3	--	--	-0.90**	4.14	-1.54
TS 56D	5(4)	103-750+	--	3	1	--	1	-0.35NS	5.15†	-2.52†
					Nakhon Sawan Area					
PD 251	18(12)	224-750+	--	--	5	7	6	-0.61**	5.20	-2.01
TS 15	18(13)	122-750+	--	--	7	6	5	-0.76*	7.93	-4.01
TS 16	14(14)	76-714	1	2	5	6	--	-0.91*	8.66	-4.18
TS 17	16(15)	122-750+	--	--	7	8	1	-0.91*	6.43	-3.06
TS 18	18(0)	720+-750+	--	--	--	2	16	Insufficient data		
TS 19	14(8)	105-750+	--	1	4	3	6	-0.93*	4.74	-2.08
TS 20	17(16)	204-750+	--	--	8	8	1	-0.67*	6.19	-2.55
					Lop Buri Area					
PD 252	20(19)	154-750+	--	--	17	2	1	-0.39NS	8.92†	-4.15†
PD 253	20(20)	170-716	--	--	11	9	--	-0.83*	8.78	-4.21
PD 254	20(18)	110-750+	--	1	9	8	2	-0.61*	8.50	-4.11
PD 255	19(17)	88-750+	--	9	5	3	2	-0.93*	5.85	-2.73
PD 256	19(16)	108-750+	--	1	13	2	3	-0.75*	7.99	-4.07
TS 21	18(15)	61-750+	1	7	4	3	3	-0.75*	9.19	-5.18
TS 22	15(13)	67-750+	1	4	5	3	2	-0.93*	7.93	-4.19
TS 23	18(15)	147-750+	--	--	11	4	3	-0.85*	5.20	-2.04
TS 24	17(14)	153-750+	--	--	10	4	3	-0.72*	5.74	-2.40
TS 25	17(0)	750+	--	--	--	--	17	No data within penetrometer dial range		
TS 25A	5(5)	316+-638+	--	--	--	5	--	-0.18NS	12.23†	-7.39†
TS 25B	5(5)	152-332+	--	--	2	3	--	-0.32NS	11.54†	-6.38†
TS 26	16(16)	119-408	--	1	14	1	--	-0.77*	7.11	-3.09

(Continued)

Note: >749 CI values not used in correlations.
Numbers in parentheses denote number of measurements used in correlations.
NS = not significant, >5% level.
* Highly significant, ≤1% level.
** Significant, 1% to 5% level.
† Determined from line of best fit.

Table 3 (Concluded)

Site No.	No. of Measurements	Range of CI	No. of Measurements Within CI Increments of <80	80-119	120-299	300-749	>749	Correlation Coefficient	Specific Equation Constants Intercept	Slope
					Bangkok Area					
PD 244	22(20)	56-750†	12	4	3	1	2	-0.93*	10.14	-5.37
PD 245	21(20)	61-750†	4	6	7	3	1	-0.86*	9.88	-5.10
TS 8	17(17)	42-107	14	3	--	--	--	-0.52*	6.06	-2.53
					Pran Buri Area					
PD 257	16(6)	164-750†	--	--	2	4	10	-0.88**	3.41	-1.05
TS 29	16(15)	172-750†	--	--	9	6	1	-0.64*	6.16	-3.10
TS 30	16(13)	52-750†	1	--	4	8	3	-0.90*	3.98	-1.68
TS 31	17(10)	39-750†	3	1	2	4	7	-0.94*	4.93	-2.54
TS 32	18(14)	41-750†	3	2	3	6	4	-0.93*	4.56	-2.39
TS 33	16(9)	78-750†	1	2	3	3	7	-0.81*	5.43	-2.70
TS 34	17(13)	44-750†	3	1	1	8	4	-0.78*	5.54	-2.90
					Chanthaburi Area					
PD 258	24(17)	100-750†	--	1	11	5	7	-0.89*	7.89	-3.81
PD 259	23(23)	82-482	--	3	11	9	--	-0.96*	6.67	-2.79
TS 35	23(17)	28-750†	1	5	7	4	6	-0.96*	4.13	-1.98
TS 36	22(18)	56-750†	1	2	9	6	4	-0.96*	5.31	-2.65
TS 37	23(12)	202-750†	--	--	4	8	11	-0.89*	5.78	-2.88
TS 38	20(20)	91-250	--	5	15	--	--	-0.12NS	6.48†	-2.16†
TS 39	21(12)	183-750†	--	--	5	7	9	-0.79*	4.78	-2.07
TS 40	21(20)	100-750†	--	2	10	8	1	-0.97*	5.94	-2.24
TS 41	23(23)	111-735	--	1	14	8	--	-0.92*	5.22	-2.38
TS 42	23(21)	119-750†	--	1	11	9	2	-0.96*	5.78	-2.61
					Hat Yai Area					
PD 260	20(20)	129-679	--	--	12	8	--	-0.84*	4.10	-1.63
TS 43	20(16)	89-750†	--	4	6	6	4	-0.93*	5.44	-2.59
TS 44	19(8)	541-750†	--	--	--	8	11	-0.81*	4.24	-1.27
TS 45	17(16)	176-750†	--	--	1	15	1	-0.68*	4.34	-1.50
TS 46	16(16)	109-337	--	2	12	2	--	-0.46NS	10.22†	-6.39†
TS 47	20(20)	150-623	--	--	13	7	--	-0.69*	7.59	-3.62
TS 48	20(16)	134-750†	--	--	12	4	4	-0.49NS	6.31†	-3.16†
TS 49	19(19)	73-310	1	7	10	1	--	-0.52**	4.57	-1.48
TS 50	20(20)	113-253	--	--	20	--	--	-0.60*	2.76	-0.49

* Highly significant, ≤1% level.
** Significant, 1% to 5% level.
† Determined from line of best fit.

Table 4

Summary of RI Ranges and RI-MC Relations

Site No.	No. of Measure-ments	Range of RI	No. of Measurements Within RI Increments				Too Firm to Sample	Correlation Coefficient	Specific Equation Constants		Mean RI
			<0.50	0.50-0.79	0.80-1.19	>1.20			Inter-cept	Slope	
					Chiang Mai Area						
PD 241	24 (17)	0.29-1.19	4	9	4	--	7	-0.15NS	--	--	0.68
PD 242	25 (18)	0.48-5.30	1	1	2	14	7	-0.39NS	--	--	2.65
PD 243	25 (16)	0.36-1.78	6	7	2	1	9	-0.59*	4.18	-0.23	0.65
TS 1	20 (3)	0.75-1.16	--	1	2	--	17	+0.88NS	--	--	1.01
TS 2	23 (14)	0.64-1.66	--	2	8	4	9	-0.39NS	--	--	1.02
TS 3	15 (15)	0.82-2.45	--	--	6	9	--	-0.50NS	--	--	1.47
TS 4	21 (20)	0.69-1.16	--	3	17	--	1	-0.49*	1.34	-0.02	0.91
TS 5	21 (11)	0.84-2.56	--	--	4	7	10	-0.50NS	--	--	1.73
TS 6	20 (19)	0.35-1.26	2	8	8	1	1	-0.29NS	--	--	0.79
TS 7	12 (12)	0.65-1.67	--	4	3	5	--	-0.46NS	--	--	1.10
TS 19B	9 (9)	0.52-3.04	--	1	--	8	--	-0.65NS	--	--	2.04
TS 19C	10 (10)	0.17-0.50	9	1	--	--	--	-0.25NS	--	--	0.36
TS 19E	10 (9)	0.86-2.79	--	--	1	9	--	-0.48NS	--	--	2.11
					Khon Kaen Area						
PD 246	19 (12)	1.07-4.45	--	--	1	11	7	+0.25NS	--	--	1.98
PD 247	16 (9)	0.30-2.24	3	4	1	1	7	-0.94**	4.47	-0.24	0.78
PD 248	18 (14)	0.29-2.64	1	4	3	6	4	-0.52NS	--	--	1.26
PD 249	16 (9)	0.69-1.58	--	1	3	5	7	-0.44NS	--	--	1.17
TS 9	18 (16)	0.86-2.35	--	--	3	13	2	+0.28NS	--	--	1.51
TS 10	17 (11)	1.19-4.47	--	--	1	10	6	+0.14NS	--	--	2.50
TS 11	18 (17)	0.42-2.72	1	--	7	9	1	-0.57*	4.82	-0.24	1.39
TS 12	17 (6)	0.46-1.72	2	3	--	1	11	-0.91*	4.96	-0.21	0.77
TS 13	18 (9)	0.38-3.20	1	2	3	3	9	-0.96**	4.54	-0.19	1.14
TS 14	15 (8)	0.70-1.97	--	3	3	2	7	-0.67NS	--	--	1.07
TS 56A	6 (5)	0.74-1.04	--	3	2	--	1	-0.60NS	--	--	0.87
TS 56B	5 (5)	0.54-0.94	--	3	2	--	--	-0.96**	1.81	-0.05	0.76
TS 56D	5 (4)	0.54-0.82	--	3	1	--	1	-0.94NS	--	--	0.69
					Nakhon Sawan Area						
PD 251	17 (8)	0.75-1.55	--	1	2	5	9	+0.07NS	--	--	1.17
TS 15	18 (11)	0.86-1.80	--	--	6	5	7	-0.23NS	--	--	1.13
TS 16	13 (13)	0.96-1.69	--	--	9	4	--	-0.30NS	--	--	1.21
TS 17	15 (13)	0.90-1.61	--	--	6	7	2	-0.75**	2.37	-0.06	1.24
TS 18	18 (0)	--	No data (too firm for core sampling)					--	--	--	--
TS 19	14 (6)	0.53-1.69	--	4	1	1	8	-0.97**	2.80	-0.12	0.87
TS 20	15 (11)	1.10-1.39	--	--	6	5	4	+0.15NS	--	--	1.22
					Lop Buri Area						
PD 252	20 (19)	1.04-1.38	--	--	13	6	1	+0.12NS	--	--	1.15
PD 253	20 (18)	0.86-1.31	--	--	16	2	2	-0.20NS	--	--	1.11
PD 254	20 (16)	1.06-1.96	--	--	8	8	4	-0.64**	2.84	-0.05	1.27
PD 255	19 (16)	0.72-1.28	--	2	12	2	3	-0.37NS	--	--	0.96
PD 256	19 (15)	0.75-1.40	--	1	12	2	4	-0.30NS	--	--	1.07
TS 21	17 (14)	0.75-1.64	--	1	7	6	3	-0.57*	2.21	-0.05	1.16
TS 22	15 (11)	0.68-1.21	--	3	7	1	4	-0.06NS	--	--	0.98
TS 23	18 (13)	0.59-1.47	--	2	7	4	5	-0.28NS	--	--	1.10
TS 24	17 (12)	0.80-1.79	--	--	7	5	5	-0.34NS	--	--	1.21

(Continued)

Note: Numbers in parentheses denote number of measurements used in correlations.
NS = not significant, >5% level.
* Significant, 1% to 5% level.
** Highly significant ≤1% level.

Table 4 (Concluded)

Site No.	No. of Measure-ments	Range of RI	No. of Measurements Within RI Increments				Too Firm to Sample	Correlation Coefficient	Specific Equation Constants		Mean RI
			<0.50	0.50-0.79	0.80-1.19	>1.20			Inter-cept	Slope	
					Lop Buri Area (Continued)						
PD 25	17 (0)	--	No data (too firm for core sampling)					--	--	--	--
PD 25A	5 (5)	0.12-0.72	3	2	--	--	--	-0.66NS	--	--	0.37
PD 25B	5 (5)	0.32-0.70	2	3	--	--	--	-0.42NS	--	--	0.54
PD 26	16 (16)	0.50-1.60	--	4	11	1	--	-0.73**	2.54	-0.04	0.92
					Bangkok Area						
PD 244	22 (19)	0.80-1.60	--	--	18	1	3	-0.68**	2.13	-0.03	1.00
PD 245	20 (18)	0.75-1.31	--	1	16	1	2	-0.21NS	--	--	1.03
TS 8	17 (17)	0.64-1.17	--	4	13	--	--	-0.27NS	--	--	0.93
					Pran Buri Area						
PD 257	16 (3)	0.78-2.99	--	1	--	2	13	0.00NS	--	--	1.78
TS 29	16 (14)	0.69-1.44	--	4	9	1	2	-0.06NS	--	--	0.89
TS 30	16 (8)	0.79-2.42	--	1	2	5	8	-0.92**	2.77	-0.11	1.65
TS 31	17 (7)	0.62-1.98	--	4	1	2	10	-0.96**	3.10	-0.14	1.03
TS 32	15 (10)	0.33-2.78	1	2	2	5	5	-0.90**	3.99	-0.23	1.52
TS 33	16 (7)	0.54-1.11	--	4	3	--	9	-0.43NS	--	--	0.76
TS 34	17 (7)	0.48-2.81	1	2	--	4	10	-0.60NS	--	--	1.46
					Chanthaburi Area						
PD 258	24 (14)	0.72-1.37	--	1	11	2	10	-0.59*	2.20	-0.04	1.07
PD 259	23 (23)	0.82-2.61	--	--	7	16	--	-0.50*	2.74	-0.03	1.54
TS 35	23 (14)	0.19-2.36	3	2	6	3	9	-0.75**	2.92	-0.17	1.08
TS 36	22 (14)	0.63-3.43	--	4	4	6	8	-0.55*	3.56	-0.15	1.35
TS 37	22 (9)	0.88-1.50	--	--	3	6	13	-0.72*	2.55	-0.10	1.25
TS 38	20 (20)	0.25-1.00	6	10	4	--	--	-0.58**	1.40	-0.01	0.63
TS 39	21 (12)	0.42-1.59	3	3	4	2	9	-0.78**	3.19	-0.19	0.82
TS 40	21 (18)	0.54-1.34	--	9	8	1	3	-0.58*	1.51	-0.01	0.87
TS 41	23 (20)	0.52-1.79	--	3	9	8	3	-0.68**	2.60	-0.09	1.14
TS 42	23 (17)	0.64-1.95	--	2	8	7	6	-0.68**	3.16	-0.10	1.20
					Hat Yai Area						
PD 260	20 (19)	0.80-2.56	--	--	3	16	1	-0.01NS	--	--	1.66
TS 43	20 (12)	0.63-4.84	--	3	4	5	8	-0.77**	7.31	-0.33	1.39
TS 44	19 (0)	0.43-0.45	2	--	--	--	17	Insufficient data			0.44
TS 45	17 (5)	0.76-2.49	--	1	--	4	12	-0.37NS	--	--	1.59
TS 46	16 (16)	0.46-1.31	--	6	9	1	--	+0.39NS	--	--	0.86
TS 47	20 (18)	0.77-1.92	--	2	7	9	2	-0.26NS	--	--	1.28
TS 48	20 (15)	0.48-1.54	1	8	5	1	5	-0.05NS	--	--	0.77
TS 49	19 (19)	0.67-1.50	--	7	10	2	--	-0.26NS	--	--	0.92
TS 50	19 (19)	1.45-3.48	--	--	--	19	--	-0.34NS	--	--	2.14

* Significant, 1% to 5% level.
** Highly significant, ≤1% level.

Table 5

Summary of RCI Ranges and RCI-MC Relations

Site No.	Measurements	Range of RCI	No. of Measurements Within RCI Increments of <26	26-60	61-160	161-749	>749	Correlation Coefficient	Specific Equation Constants Intercept	Slope	Minimum RCI Measured	Estimated
						Chiang Mai Area						
PD 241	24 (17)	28-750+	--	4	9	4	7	-0.54*	13.48	-8.68	28	3
PD 243	25 (18)	55-1237	--	1	3	11	10	-0.60**	6.73	-3.94	55	8
PD 244	25 (16)	53-984	--	1	6	8	10	-0.62**	16.16	-11.82	53	2
TS 1	20 (3)	340-750+	--	--	--	3	17	+0.60NS	No trend in data		340	--
TS 2	23 (14)	102-750+	--	--	4	10	9	-0.71**	11.40	-6.33	102	31
TS 3	15 (15)	73-802	--	--	5	9	1	-0.85**	8.73	-4.37	73	58
TS 4	21 (20)	70-750+	--	--	14	6	1	-0.88**	7.55	-3.95	70	68††
TS 5	21 (11)	175-750+	--	--	--	11	10	-0.81**	4.60	-1.87	175	60
TS 6	20 (19)	45-750+	--	2	14	3	1	-0.50*	7.66	-4.29	45	13
TS 7	12 (12)	172-681	--	--	--	12	--	-0.77**	5.18	-1.91	172	164
TS 19B	9 (9)	90-921	--	--	1	6	2	-0.82**	8.81	-5.21	90	23
TS 19C	10 (10)	25-82	1	3	6	--	--	-0.41NS	6.88†	-4.07†	25	17†
TS 19E	10 (10)	169-743	--	--	--	10	--	-0.76**	4.60	-1.90	169	229††
						Khon Kaen Area						
PD 246	19 (12)	305-810	--	--	--	11	8	-0.06NS	No trend in data		305	--
PD 247	16 (9)	54-1346	--	1	4	3	8	-0.95**	9.15	-5.89	54	6
PD 248	18 (14)	118-1205	--	--	2	6	10	-0.75**	7.69	-4.49	118	13
PD 249	16 (8)	310-1128	--	--	--	6	10	-0.71*	4.03	-1.12	310	230
TS 9	18 (16)	190-750+	--	--	--	16	2	-0.63**	3.55	-1.08	190	116
TS 10	17 (11)	104-1341	--	--	1	7	9	-0.75**	3.41	-1.29	104	69
TS 11	18 (17)	103-1409	--	--	1	14	3	-0.80**	11.01	-7.21	103	44
TS 12	17 (6)	67-1003	--	--	5	--	12	-0.90*	14.14	-9.23	67	13
TS 13	18 (9)	42-1670	--	2	4	1	11	-0.96**	6.92	-3.78	42	55
TS 14	15 (8)	87-920	--	--	2	5	8	-0.88**	11.76	-6.73	87	9
TS 56A	6 (5)	107-750+	--	--	3	2	1	-0.90*	6.67	-3.38	107	53
TS 56B	5 (5)	57-165	--	1	3	1	--	-0.97**	5.61	-2.73	57	60
TS 56D	5 (4)	56-750+	--	1	3	--	1	-0.87NS	4.68†	-2.05†	56	23†
						Nakhon Sawan Area						
PD 251	17 (8)	249-750+	--	--	--	8	9	-0.55NS	10.13†	-5.67†	249	84†
TS 15	18 (11)	107-750+	--	--	1	9	8	-0.68*	9.17	-4.88	107	30
TS 16	13 (13)	101-1135	--	--	6	5	2	-0.89**	9.62	-4.78	101	19
TS 17	15 (13)	110-927	--	--	1	9	5	-0.90**	8.56	-4.61	110	8
TS 18	--	--	No data for remolding index					--	--	--	--	--
TS 19	14 (6)	56-750+	--	1	3	2	8	-0.98**	6.77	-3.87	56	38
TS 20	15 (11)	251-750+	--	--	--	11	4	-0.27NS	13.46†	-7.51†	251	66†
						Lop Buri Area						
PD 252	20 (19)	163-750+	--	--	--	19	1	-0.33NS	12.64†	-6.47†	163	21†
PD 253	20 (18)	187-750+	--	--	--	18	2	-0.70**	8.80	-4.20	187	43
PD 254	20 (16)	133-1035	--	--	1	14	5	-0.66**	10.10	-5.14	133	141
PD 255	19 (16)	81-750+	--	--	12	4	3	-0.84**	6.63	-3.32	81	43
PD 256	19 (15)	109-750+	--	--	7	8	4	-0.58**	7.74	-3.88	109	52
TS 21	17 (14)	74-920	--	--	8	5	4	-0.79**	10.59	-6.19	74	93
TS 22	15 (11)	62-750+	--	--	7	4	4	-0.80**	9.63	-5.43	62	34
TS 23	18 (12)	110-750+	--	--	2	11	5	-0.57*	6.90	-3.25	110	143

(Continued)

Note: Numbers in parentheses denote number of measurements used in correlations.
NS = not significant, >5% level.
* Significant, 1% to 5% level.
** Highly significant, ≤1% level.
† Determined from line of best visual fit.
†† Estimated at high measured MC.

Table 5 (Concluded)

Site No.	Measurements	Range of RCI	No. of Measurements Within RCI Increments of <26	26-60	61-160	161-749	>749	Correlation Coefficient	Specific Equation Constants Intercept	Slope	Minimum RCI Measured	Estimated
					Lop Buri Area (Continued)							
TS 24	17 (12)	157-750+	--	--	1	11	5	-0.39NS	7.23†	-3.42†	157	55
TS 25	--	--	No data for remolding index					--	--	--	--	--
TS 25A	5 (5)	38-250	--	1	2	2	--	-0.73NS	15.83†	-10.56†	38	11†
TS 25B	5 (5)	82-232	--	--	3	2	--	-0.60NS	16.68†	-10.87†	82	81†
TS 26	16 (16)	70-653	--	--	10	6	--	-0.83**	9.94	-4.91	70	23
					Bangkok Area							
PD 244	22 (19)	46-1198	--	3	13	2	4	-0.91**	12.34	-6.81	46	29
PD 245	20 (18)	46-750+	--	1	9	8	2	-0.78**	10.37	-5.42	46	70
TS 8	17 (17)	35-125	--	12	5	--	--	-0.60**	6.80	-2.99	35	50
					Pran Buri Area							
PD 257	16 (3)	257-750+	--	--	--	3	13	-0.48NS	No trend in data		257	--
TS 29	16 (14)	129-750+	--	--	3	11	2	-0.47NS	9.48†	-5.87†	129	91†
TS 30	16 (8)	41-750+	--	1	--	4	9	-0.93**	5.04	-2.60	41	84
TS 31	17 (7)	25-962	2	1	2	1	10	-0.94**	7.17	-4.50	25	20
TS 32	15 (10)	18-1195	3	--	2	2	11	-0.94**	7.17	-4.87	18	11
TS 33	16 (7)	42-750+	--	1	2	4	9	-0.74NS	5.86†	-3.04†	42	17†
TS 34	17 (7)	23-1322	1	2	--	3	11	-0.71NS	5.83†	-3.29†	23	19†
					Chanthaburi Area							
PD 258	24 (14)	108-750+	--	--	2	12	10	-0.82**	9.93	-5.18	108	180
PD 259	23 (23)	69-857	--	--	6	14	3	-0.91**	8.50	-3.86	69	81
TS 35	23 (14)	5-750+	1	3	6	4	9	-0.91**	6.93	-4.74	5	34
TS 36	22 (14)	35-991	--	1	6	4	11	-0.88**	8.01	-4.92	35	35
TS 37	22 (9)	183-906	--	--	--	8	14	-0.85**	7.71	-4.48	183	180
TS 38	20 (20)	34-250	--	4	15	1	--	-0.49*	8.80	-3.41	34	44††
TS 39	21 (12)	88-976	--	--	3	8	10	-0.82**	7.67	-4.81	88	28
TS 40	21 (18)	58-750+	--	1	9	8	3	-0.90**	7.55	-3.27	58	46
TS 41	23 (20)	58-893	--	1	4	14	4	-0.91**	7.06	-3.86	58	14
TS 42	23 (17)	93-841	--	--	3	13	7	-0.88**	8.41	-4.58	93	135
					Hat Yai Area							
PD 260	20 (19)	119-981	--	--	2	13	5	-0.64**	4.77	-2.09	119	141
TS 43	20 (12)	56-2623	--	1	5	5	9	-0.93**	10.66	-6.72	56	12
TS 44	19 (0)	253-750+	--	--	--	2	17	Insufficient data			253	--
TS 45	17 (5)	134-1352	--	--	1	1	15	-0.62NS	No trend in data		134	--
TS 46	16 (16)	64-228	--	--	9	7	--	-0.15NS	14.12†	-9.55†	64	10†
TS 47	20 (18)	116-938	--	--	2	15	3	-0.50*	9.34	-4.78	116	127
TS 48	20 (15)	71-750+	--	--	6	9	5	-0.19NS	9.22†	-5.67†	71	14†
TS 49	19 (19)	58-440	--	1	13	5	--	-0.48*	5.66	-2.17	58	39†
TS 50	19 (19)	201-620	--	--	--	19	--	-0.67**	3.30	-0.69	201	185

* Significant, 1% to 5% level.
** Highly significant, ≤1% level.
† Determined from line of best visual fit.
†† Estimated at high measured MC.

Table 6

Soil Moisture Accretion Relations

Site No.	Soil Layer in.	Accretion Regression Equations Class I	Class II
241	0-6	$Y = 0.66X - 0.14$	$Y = 0.51Z - 0.12$
	6-12	$Y = 0.19X - 0.03$	$Y = 0.47Z - 0.05$
242	0-6	$Y = 0.34X - 0.02$	$Y = 0.42Z - 0.02$
	6-12	$Y = 0.05X$	$Y = 0.57Z - 0.04$
243	0-6	$Y = 0.57X - 0.10$	$Y = 0.57Z - 0.03$
	6-12	$Y = 0.25X - 0.05$	$Y = 0.32Z - 0.03$
244	0-6	$Y = 0.35X + 0.06$	$Y = 1.00Z$
	6-12	$Y = 0.32X - 0.07$	$Y = 0.52Z + 0.08$
246	0-6	$Y = 0.62X - 0.06$	$Y = 0.96Z - 0.15$
	6-12	$Y = 0.46X - 0.13$	$Y = 0.73Z - 0.12$
247	0-6	$Y = 0.52X - 0.03$	$Y = 0.65Z - 0.15$
	6-12	$Y = 0.36X - 0.09$	$Y = 0.78Z - 0.16$
248	0-6	$Y = 0.34X + 0.03$	$Y = 0.96Z - 0.57$
	6-12	$Y = 0.30X - 0.08$	$Y = 0.30Z - 0.28$
251	0-6	$Y = 0.61X - 0.09$	$Y = 0.86Z - 0.03$
	6-12	$Y = 0.20X - 0.03$	$Y = 0.79Z - 0.06$
252	0-6	$Y = 0.55X - 0.07$	$Y = 0.85Z - 0.11$
	6-12	$Y = 0.12X - 0.01$	$Y = 0.70Z - 0.03$
253	0-6	$Y = 0.45X - 0.02$	$Y = 0.89Z - 0.11$
	6-12	$Y = 0.14X - 0.02$	$Y = 0.48Z - 0.09$
254	0-6	$Y = 0.70X - 0.11$	$Y = 1.01Z - 0.13$
	6-12	$Y = 0.30X - 0.05$	$Y = 0.96Z - 0.06$
255	0-6	$Y = 0.45X - 0.01$	$Y = 0.84Z - 0.11$
	6-12	$Y = 0.31X - 0.07$	$Y = 0.61Z - 0.09$
256	0-6	$Y = 0.47X - 0.08$	$Y = 0.78Z - 0.13$
	6-12	$Y = 0.37X - 0.11$	$Y = 0.54Z - 0.03$
257	0-6	$Y = 0.37X + 0.01$	$Y = 0.44Z - 0.05$
	6-12	$Y = 0.35X - 0.07$	$Y = 0.73Z - 0.13$
258	0-6	$Y = 0.56X - 0.04$	$Y = 0.83Z - 0.11$
	6-12	$Y = 0.18X - 0.04$	$Y = 0.64Z - 0.08$
259	0-6	$Y = 0.72X - 0.15$	$Y = 0.42Z - 0.04$
	6-12	$Y = 0.30X - 0.08$	$Y = 0.41Z - 0.04$
260	0-6	$Y = 0.52X - 0.03$	$Y = 0.95Z - 0.17$
	6-12	$Y = 0.27X - 0.05$	$Y = 0.61Z - 0.06$

Note: Y - estimated accretion, in. of water per 6-in. soil layer.
X - rainfall, in.
Z - available storage at start of storm, in. per 6-in. soil layer.

Table 7

Soil Moisture Depletion Curve Values

Moisture Content in Inches Per 6-in. Soil Layer

No.	Site 241 Layer		Site 242 Layer		Site 243 Layer		Site 244 Layer		Site 246 Layer		Site 247 Layer		Site 248 Layer		Site 251 Layer		Site 252 Layer		Site 253 Layer		Site 254 Layer		Site 255 Layer		Site 256 Layer		Site 257 Layer		Site 258 Layer		Site 259 Layer		Site 260 Layer	
of Days	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.	0-6 in.	6-12 in.
																	Summer																	
0	2.38	2.05	1.55	1.27	2.25	1.97	3.09	3.01	1.43	1.43	1.67	1.73	2.10	1.85	1.96	2.10	2.65	2.88	2.70	2.56	2.00	2.18	2.22	2.26	2.62	2.35	1.22	1.18	2.85	2.60	2.52	2.59	1.31	1.46
1	2.33	2.00	1.52	1.25	2.15	1.90	2.80	2.96	1.39	1.37	1.62	1.68	2.07	1.82	1.92	2.05	2.55	2.72	2.57	2.52	1.96	2.15	2.17	2.24	2.52	2.31	1.14	1.15	2.74	2.53	2.45	2.50	1.28	1.45
2	2.28	1.96	1.46	1.24	2.05	1.83	2.71	2.91	1.37	1.31	1.57	1.63	2.03	1.79	1.89	2.00	2.46	2.57	2.43	2.48	1.92	2.12	2.11	2.21	2.42	2.27	1.07	1.12	2.56	2.47	2.40	2.46	1.24	1.43
3	2.23	1.91	1.40	1.22	1.94	1.77	2.61	2.85	1.33	1.25	1.52	1.58	2.00	1.76	1.85	1.95	2.36	2.52	2.30	2.44	1.88	2.09	2.05	2.18	2.30	2.23	0.99	1.09	2.40	2.40	2.35	2.42	1.20	1.40
4	2.17	1.86	1.35	1.21	1.84	1.70	2.52	2.80	1.25	1.19	1.47	1.53	1.96	1.73	1.76	1.90	2.27	2.50	2.20	2.39	1.84	2.05	2.00	2.16	2.20	2.19	0.90	1.06	2.31	2.33	2.30	2.38	1.17	1.38
5	2.12	1.82	1.29	1.19	1.74	1.63	2.43	2.76	1.22	1.13	1.42	1.48	1.93	1.71	1.67	1.86	2.21	2.48	2.12	2.37	1.78	2.02	1.95	2.14	2.14	2.15	0.84	1.03	2.18	2.26	2.26	2.35	1.15	1.36
6	2.07	1.77	1.23	1.18	1.64	1.58	2.34	2.72	1.10	1.07	1.37	1.43	1.90	1.68	1.58	1.80	2.15	2.47	2.04	2.36	1.73	1.99	1.90	2.11	2.07	2.14	0.76	1.00	2.04	2.20	2.21	2.32	1.12	1.34
7	2.02	1.72	1.17	1.17	1.55	1.52	2.24	2.68	0.98	1.01	1.31	1.38	1.86	1.65	1.49	1.76	2.09	2.45	1.98	2.34	1.67	1.94	1.85	2.08	2.00	2.12	0.69	0.96	1.88	2.13	2.16	2.29	1.09	1.32
8	1.97	1.67	1.10	1.15	1.45	1.47	2.15	2.64	0.87	0.95	1.26	1.33	1.83	1.62	1.40	1.71	2.03	2.44	1.91	2.33	1.57	1.90	1.80	2.06	1.94	2.11	0.61	0.93	1.67	2.06	2.03	2.26	1.07	1.30
9	1.92	1.62	1.02	1.14	1.36	1.43	2.06	2.59	0.75	0.88	1.21	1.28	1.80	1.59	1.33	1.66	1.97	2.41	1.85	2.31	1.47	1.85	1.76	2.04	1.88	2.09	0.54	0.90	1.53	2.00	1.90	2.23	1.04	1.28
10	1.86	1.57	0.95	1.13	1.26	1.38	2.00	2.52	0.51	0.82	1.16	1.24	1.76	1.56	1.25	1.62	1.92	2.39	1.80	2.30	1.37	1.80	1.71	2.01	1.81	2.06	0.46	0.87	1.49	1.93	1.77	2.21	1.00	1.26
12	1.76	1.47	0.80	1.11	0.94	1.30	1.89	2.31	0.34	0.70	1.05	1.16	1.64	1.50	1.12	1.52	1.80	2.34	1.72	2.25	1.24	1.62	1.60	1.96	1.72	2.00	0.31	0.81	1.46	1.87	1.59	2.15	0.88	1.22
14	1.58	1.37	0.68	1.09	0.81	1.21	1.77	2.05	0.29	0.56	0.93	1.08	1.52	1.45	0.99	1.45	1.72	2.27	1.67	2.19	1.19	1.57	1.44	1.91	1.66	1.95	0.20	0.75	1.43	1.81	1.49	2.09	0.72	1.20
16	1.33	1.19	0.55	1.08	0.75	1.12	1.68	1.92	0.26	0.40	0.82	0.99	1.40	1.39	0.95	1.38	1.63	2.21	1.63	2.12	1.17	1.53	1.28	1.86	1.61	1.89	0.15	0.68	1.43	1.75	1.41	2.03	0.56	1.16
18	1.04	1.03	0.43	1.06	0.72	1.03	1.60	1.83	0.25	0.31	0.70	0.91	1.28	1.33	0.91	1.31	1.57	2.15	1.59	2.06	1.14	1.50	1.17	1.81	1.57	1.84	0.13	0.57	1.42	1.69	1.29	1.97	0.52	1.14
20	0.80	0.99	0.35	1.05	0.70	0.95	1.55	1.75	0.24	0.28	0.61	0.83	1.16	1.27	0.86	1.24	1.52	2.11	1.55	2.00	1.12	1.48	1.11	1.75	1.54	1.78	0.12	0.46	1.41	1.63	1.27	1.92	0.50	1.10
25	0.70	0.90	0.27	1.02	0.64	0.81	1.44	1.67	0.23	0.26	0.45	0.73	0.82	1.10	0.79	1.18	1.39	2.04	1.45	1.87	1.06	1.43	1.02	1.54	1.47	1.65	0.09	0.30	1.40	1.56	1.24	1.77	0.48	1.03
30	0.66	0.84	0.26	0.97	0.59	0.74	1.41	1.66	0.23	0.25	0.38	0.68	0.41	0.93	0.74	1.12	1.31	2.02	1.35	1.80	1.00	1.40	0.98	1.26	1.41	1.56	0.07	0.23	1.39	1.51	1.22	1.65	0.46	0.93
35	0.64	0.79	0.24	0.83	0.55	0.70			0.22	0.24	0.33	0.64	0.34	0.75	0.70	1.09	1.28	2.01	1.28	1.75	0.95	1.36	0.94	1.15	1.35	1.50		0.19	1.38	1.49		1.58	0.44	0.82
40	0.62	0.75	0.23	0.62	0.51	0.66			0.20	0.23	0.31	0.61	0.30	0.57	0.68	1.05	1.27	2.00	1.23	1.71	0.90	1.34	0.90	1.09	1.30	1.45		0.17		1.48		1.54	0.42	0.71
50		0.69	0.21	0.39	0.44	0.58			0.18			0.55	0.24	0.33	0.65	1.02		1.99		1.67	0.80	1.30	0.84	1.02	1.20	1.40		0.14		1.46		1.51	0.40	0.58
60		0.65	0.20	0.33	0.41	0.51			0.17			0.50		0.22	0.62								0.78	0.98	1.12	1.36				1.45				0.54
70		0.64	0.19	0.29	0.40	0.45						0.48		0.17	0.60								0.75	0.93	1.05	1.33				1.44				
80		0.63	0.18	0.26		0.41								0.16										0.90	1.00	1.31								
90		0.62		0.24																				0.87										
100		0.61		0.22																														
125				0.19																														
																	Winter																	
0	2.38	2.05	1.55	1.27	2.25	1.97	3.09	3.01	1.43	1.43	1.67	1.73	2.10	1.85	1.96	2.10	2.65	2.88	2.70	2.56	2.00	2.18	2.22	2.26	2.62	2.35	1.22	1.18	2.85	2.60	2.52	2.59	1.31	1.46
1	2.34	2.01	1.52	1.25	2.20	1.93	3.01	2.99	1.40	1.39	1.65	1.72	2.07	1.83	1.93	2.05	2.60	2.78	2.64	2.53	1.96	2.16	2.18	2.24	2.55	2.32	1.17	1.15	2.74	2.53	2.45	2.50	1.29	1.45
2	2.29	1.96	1.46	1.24	2.15	1.90	2.93	2.97	1.38	1.36	1.63	1.71	2.03	1.81	1.90	2.00	2.55	2.68	2.58	2.50	1.93	2.14	2.14	2.22	2.47	2.29	1.11	1.12	2.56	2.47	2.40	2.46	1.27	1.44
3	2.25	1.92	1.40	1.22	2.10	1.86	2.84	2.95	1.35	1.32	1.61	1.69	2.00	1.79	1.87	1.95	2.49	2.57	2.53	2.47	1.89	2.13	2.10	2.21	2.40	2.25	1,06	1.09	2.40	2.40	2.35	2.42	1.23	1.42
4	2.20	1.88	1.35	1.21	2.05	1.83	2.76	2.93	1.30	1.28	1.59	1.68	1.96	1.77	1.80	1.90	2.44	2.52	2.47	2.44	1.86	2.11	2.06	2.19	2.36	2.22	1.00	1.06	2.31	2.33	2.30	2.38	1.21	1.40
5	2.16	1.83	1.29	1.19	2.01	1.79	2.68	2.91	1.25	1.25	1.56	1.67	1.93	1.75	1.73	1.86	2.40	2.50	2.41	2.40	1.82	2.09	2.04	2.17	2.33	2.19	0.95	1.03	2.18	2.26	2.26	2.36	1.17	1.39
6	2.12	1.79	1.25	1.18	1.96	1.75	2.60	2.89	1.21	1.21	1.54	1.65	1.90	1.73	1.66	1.80	2.36	2.49	2.38	2.39	1.78	2.07	2.00	2.15	2.30	2.17	0.89	1.00	2.04	2.22	2.21	2.33	1.15	1.38
7	2.08	1.75	1.21	1.17	1.91	1.72	2.52	2.86	1.16	1.18	1.52	1.64	1.86	1.71	1.59	1.76	2.31	2.47	2.35	2.38	1.75	2.05	1.96	2.14	2.26	2.16	0.84	0.98	1.90	2.19	2.16	2.31	1.11	1.36
8	2.03	1.70	1.17	1.15	1.86	1.69	2.46	2.84	1.10	1.14	1.50	1.63	1.83	1.69	1.52	1.71	2.27	2.46	2.32	2.37	1.71	2.04	1.93	2.12	2.23	2.15	0.78	0.95	1.77	2.16	2.03	2.29	1.08	1.34
9	1.99	1.66	1.13	1.14	1.81	1.65	2.41	2.81	1.03	1.11	1.48	1.62	1.80	1.67	1.44	1.66	2.23	2.44	2.29	2.36	1.67	2.02	1.89	2.10	2.19	2.14	0.73	0.92	1.68	2.12	1.91	2.26	1.05	1.33
10	1.95	1.62	1.09	1.13	1.76	1.61	2.35	2.79	0.97	1.07	1.46	1.61	1.76	1.65	1.37	1.62	2.19	2.43	2.26	2.34	1.62	2.00	1.86	2.08	2.16	2.12	0.68	0.89	1.61	2.09	1.88	2.24	1.01	1.32
12	1.86	1.53	1.00	1.11	1.68	1.55	2.25	2.72	0.82	1.01	1.42	1.58	1.67	1.61	1.22	1.52	2.12	2.40	2.22	2.32	1.54	1.96	1.78	2.05	2.10	2.09	0.54	0.83	1.53	2.03	1.81	2.19	0.95	1.29
14	1.77	1.46	0.89	1.09	1.61	1.48	2.14	2.62	0.65	0.95	1.34	1.52	1.63	1.57	1.18	1.45	2.06	2.37	2.18	2.30	1.45	1.91	1.70	2.02	2.03	2.05	0.39	0.77	1.50	1.98	1.74	2.13	0.88	1.26
16	1.67	1.39	0.79	1.08	1.55	1.42	2.05	2.53	0.52	0.88	1.23	1.45	1.59	1.53	1.15	1.38	1.99	2.34	2.14	2.28	1.37	1.86	1.62	1.98	1.97	2.00	0.30	0.71	1.47	1.92	1.68	2.08	0.81	1.23
18	1.53	1.32	0.71	1.06	1.51	1.38	1.96	2.43	0.45	0.82	1.14	1.38	1.55	1.49	1.11	1.34	1.93	2.31	2.09	2.26	1.34	1.78	1.55	1.95	1.90	1.94	0.24	0.64	1.45	1.87	1.63	2.02	0.74	1.21
20	1.32	1.25	0.64	1.05	1.47	1.33	1.89	2.34	0.39	0.75	1.05	1.30	1.52	1.45	1.08	1.31	1.86	2.28	2.05	2.25	1.31	1.71	1.48	1.92	1.83	1.89	0.19	0.57	1.44	1.81	1.59	1.97	0.67	1.18
25	0.98	1.10	0.45	1.02	1.38	1.25	1.80	2.16	0.29	0.59	0.83	1.11	1.46	1.35	1.02	1.23	1.73	2.21	1.95	2.20	1.26	1.53	1.32	1.82	1.70	1.74	0.13	0.39	1.42	1.67	1.51	1.83	0.56	1.11
30	0.84	1.02	0.35	0.97	1.28	1.17	1.71	2.04	0.26	0.40	0.60	0.94	1.40	1.25	0.98	1.20	1.63	2.16	1.86	2.16	1.21	1.48	1.20	1.70	1.58	1.61	0.11	0.27	1.41	1.56	1.44	1.73	0.51	1.03
35	0.79	0.96	0.32	0.83	1.19	1.09	1.65	1.94	0.23	0.29	0.54	0.83	1.34	1.18	0.94	1.17	1.55	2.12	1.81	2.13	1.16	1.44	1.15	1.53	1.50	1.53	0.10	0.22	1.40	1.52	1.38	1.68	0.48	0.89
40	0.74	0.92	0.29	0.62	1.10	1.03	1.59	1.84	0.22	0.27	0.51	0.74	1.25	1.14	0.90	1.14	1.48	2.09	1.77	2.10	1.11	1.42	1.13	1.39	1.46	1.48	0.09	0.19	1.40	1.49	1.33	1.64	0.44	0.77
50	0.67	0.85	0.25	0.39	0.95	0.93	1.49	1.71	0.20	0.24	0.46	0.66	1.00	1.05	0.83	1.11	1.39	2.06	1.67	2.03	1.00	1.38	1.09	1.21	1.39	1.44	0.07	0.16	1.38	1.46	1.26	1.59	0.41	0.68
60	0.65	0.80	0.22	0.33	0.84	0.86	1.41	1.66	0.18	0.23	0.43	0.62	0.60	0.97	0.77	1.09	1.36	2.04	1.58	1.97	0.90	1.35	1.05	1.13	1.32	1.41		0.14		1.45	1.25	1.56	0.40	0.61
70	0.63	0.76	0.21	0.29	0.75	0.79			0.17		0.41	0.59	0.45	0.89	0.71	1.08	1.31	2.01	1.49	1.91	0.80	1.32	1.00	1.08	1.26	1.38				1.44	1.24	1.53		0.57
80	0.62	0.73	0.20	0.26	0.66	0.73					0.38	0.56	0.39	0.82	0.67	1.06	1.28	1.99	1.41	1.85		1.30	0.96	1.04	1.20	1.35					1.22	1.52		0.54
90		0.70	0.18	0.24	0.57	0.67					0.35	0.53	0.37	0.72	0.63	1.05	1.27		1.33	1.80			0.91	1.00	1.14	1.31						1.51		
100		0.67		0.22	0.49	0.60					0.33	0.50	0.34	0.59	0.60	1.04			1.23	1.75			0.84	0.96	1.08									
125		0.61		0.19	0.40	0.45					0.31	0.48	0.30	0.32		1.02				1.67			0.75	0.87	1.00									
150						0.41							0.24	0.16																				

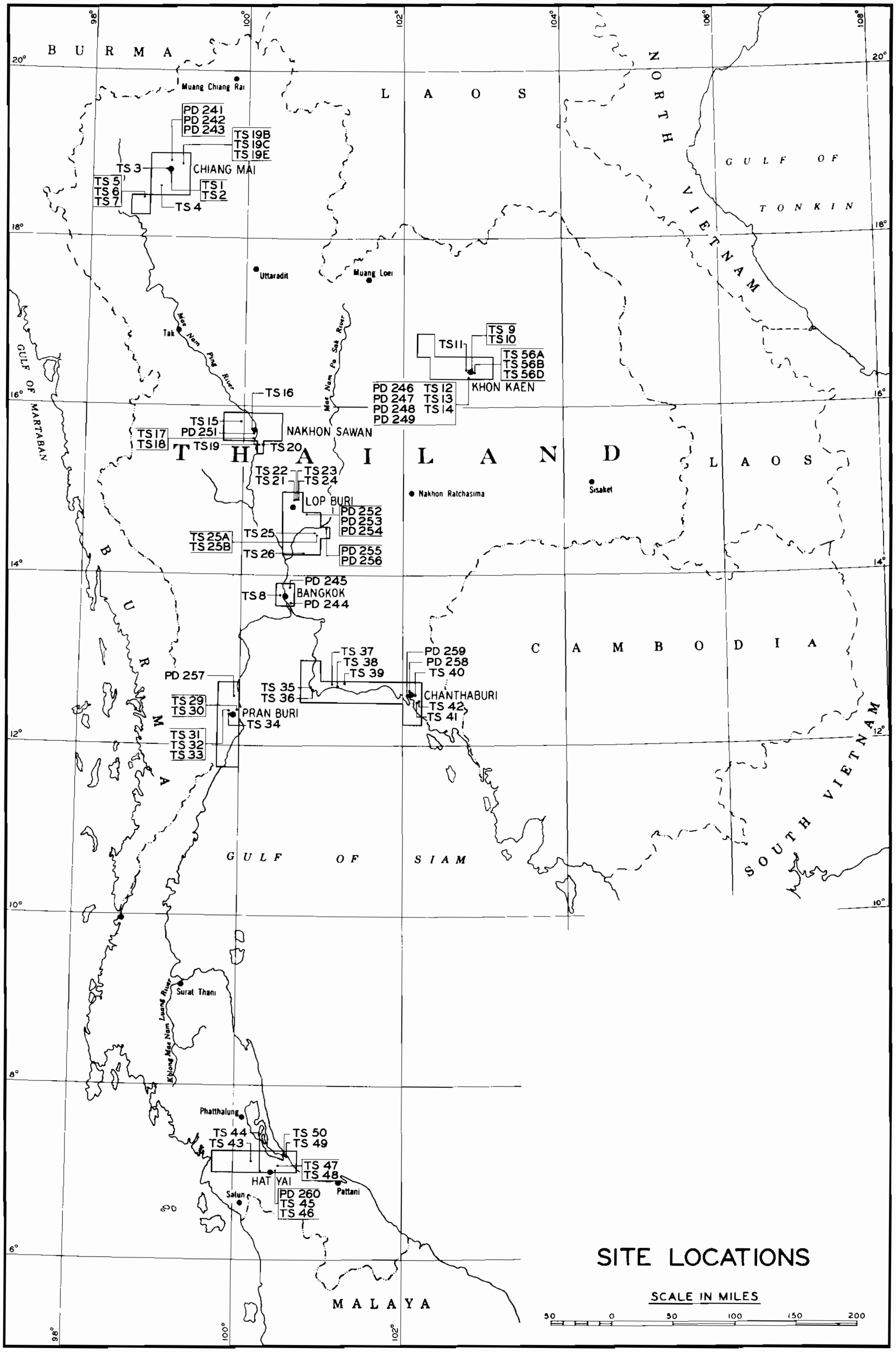
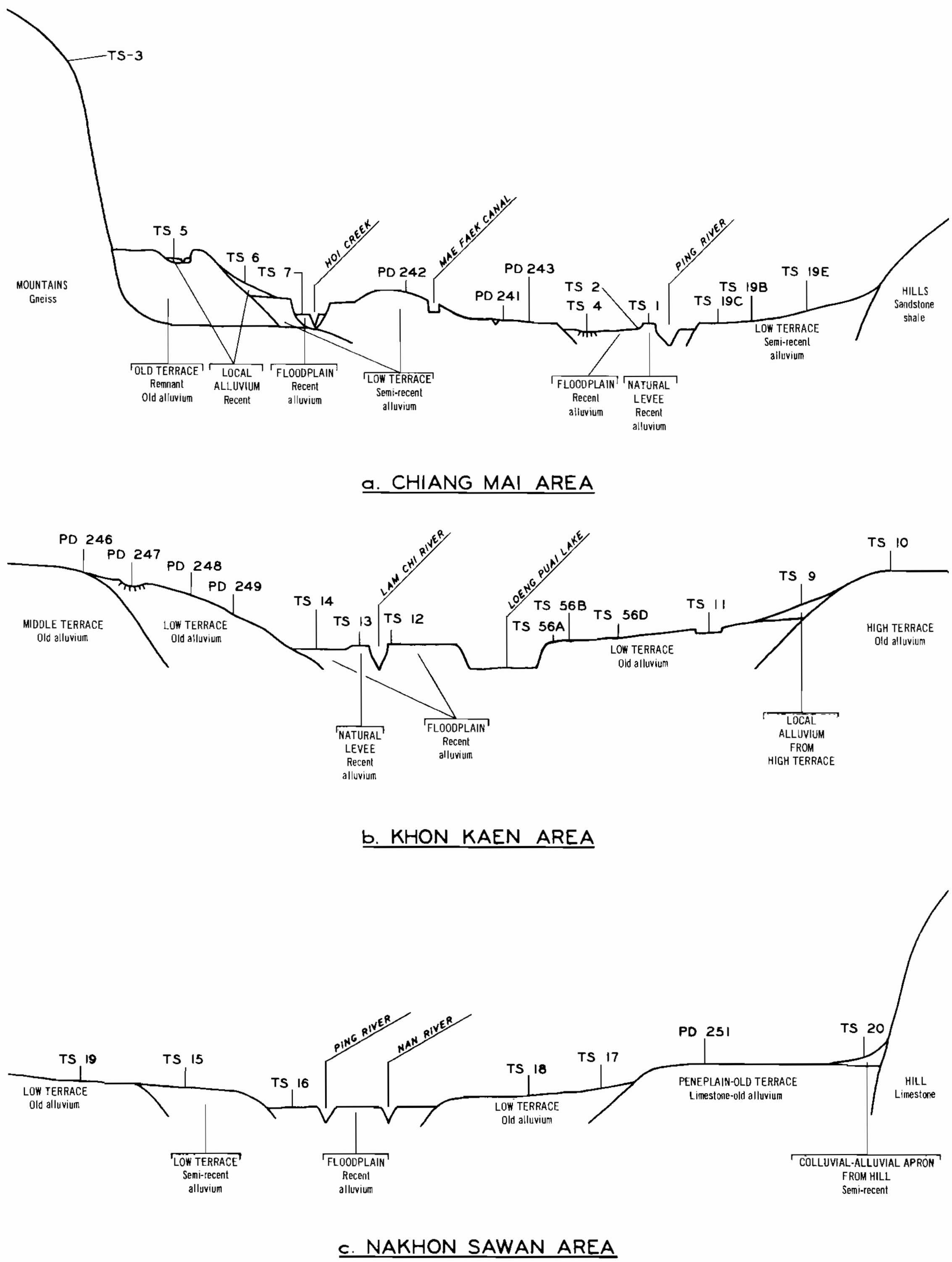

BURMA
LAOS
NORTH VIETNAM
GULF OF TONKIN
Muang Chiang Rai
PD 241
PD 242
PD 243
TS 19B
TS 19C
TS 19E
TS 3
CHIANG MAI
TS 5
TS 6
TS 7
TS 1
TS 2
TS 4
Uttaradit
Muang Loei
Tak
Mae Nam Ping River
Mae Nam Pa Sak River
TS 9
TS 10
TS 11
TS 56A
TS 56B
TS 56D
KHON KAEN
PD 246
PD 247
PD 248
PD 249
TS 12
TS 13
TS 14
TS 16
TS 15
PD 251
NAKHON SAWAN
TS 17
TS 18
TS 19
TS 20
GULF OF MARTABAN
THAILAND
TS 22
TS 21
TS 23
TS 24
LOP BURI
Nakhon Ratchasima
Sisaket
LAOS
PD 252
PD 253
PD 254
TS 25A
TS 25B
TS 25
TS 26
PD 255
PD 256
PD 245
BANGKOK
TS 8
PD 244
CAMBODIA
TS 37
TS 38
TS 39
PD 259
PD 258
TS 40
PD 257
TS 35
TS 36
CHANTHABURI
TS 42
TS 41
TS 29
TS 30
PRAN BURI
TS 34
TS 31
TS 32
TS 33
BURMA
SOUTH VIETNAM
GULF OF SIAM
Surat Thani
Khlong Mae Nam Luang River
Phatthalung
TS 50
TS 44
TS 49
TS 43
TS 47
TS 48
HAT YAI
Pattani
Satun
PD 260
TS 45
TS 46
MALAYA
SITE LOCATIONS
SCALE IN MILES
50 0 50 100 150 200
98° 100° 102° 104° 106° 108°
20° 18° 16° 14° 12° 10° 8° 6°

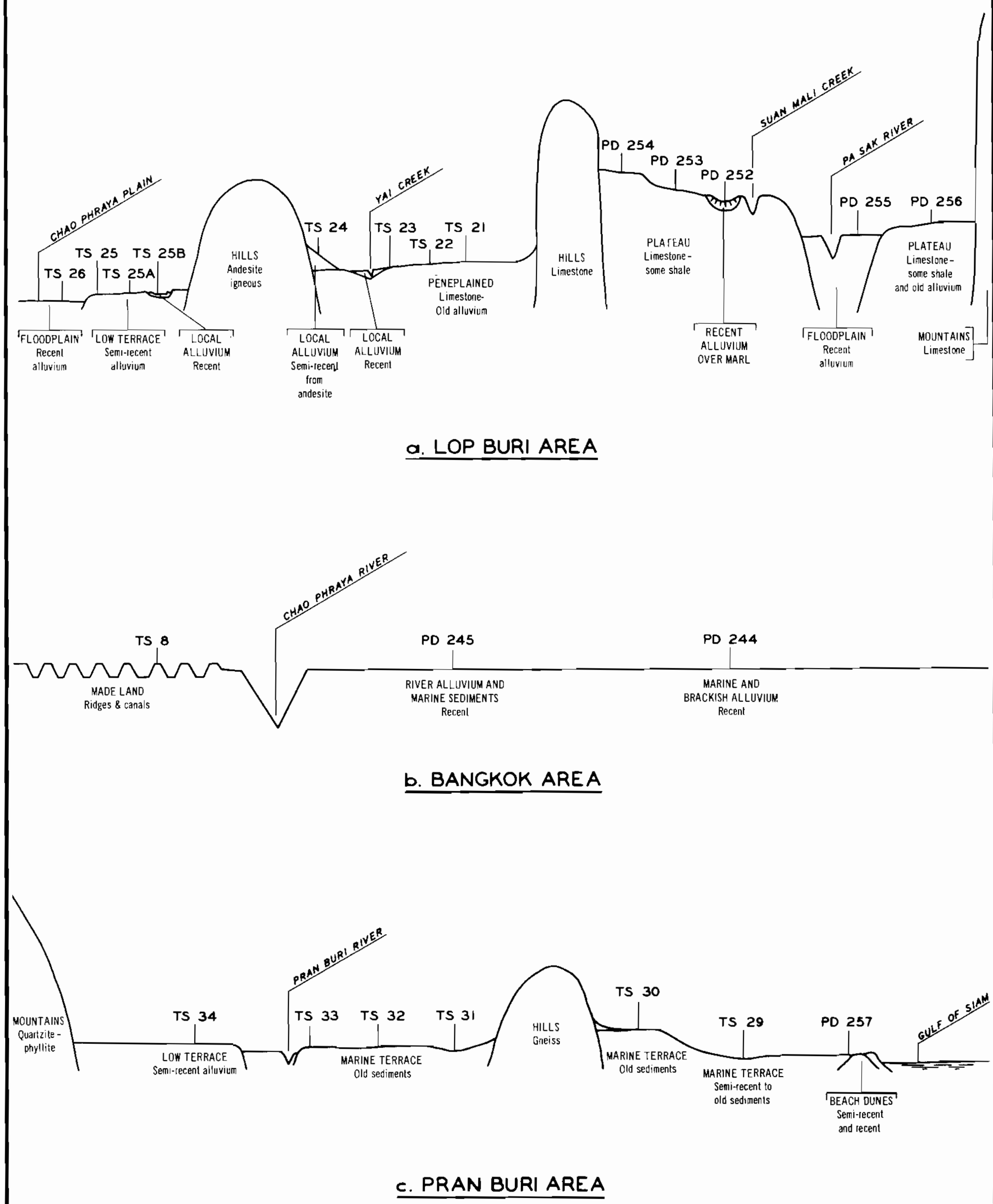
PLATE I



SCHEMATIC TRANSECTIONS

CHIANG MAI, KHON KAEN, AND
NAKHON SAWAN STUDY AREAS

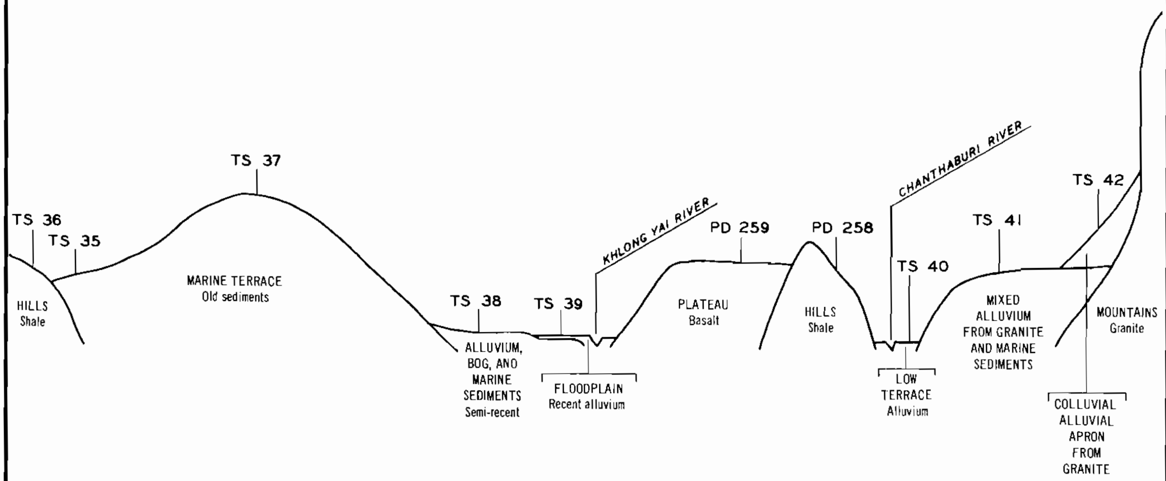
PLATE 2



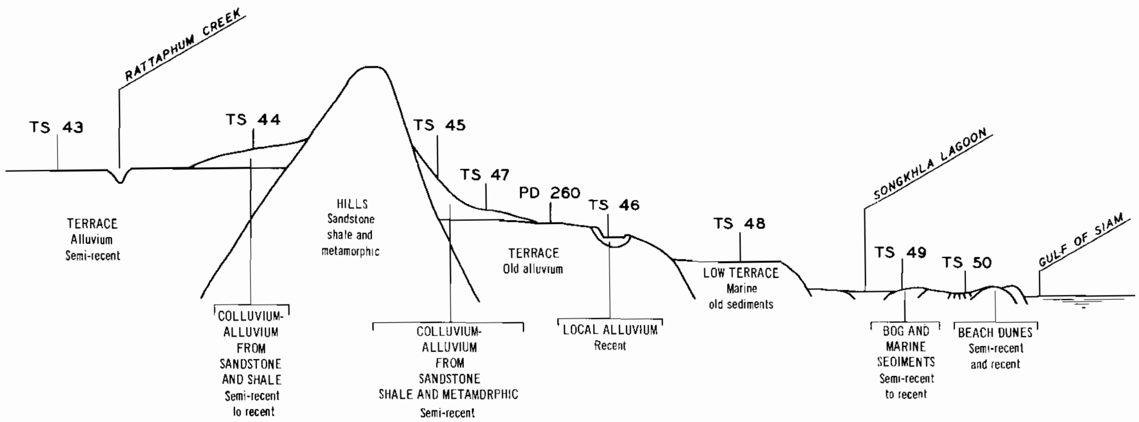
SCHEMATIC TRANSECTIONS

LOP BURI, BANGKOK, AND PRAN BURI
STUDY AREAS

PLATE 3



a. CHANTHABURI AREA

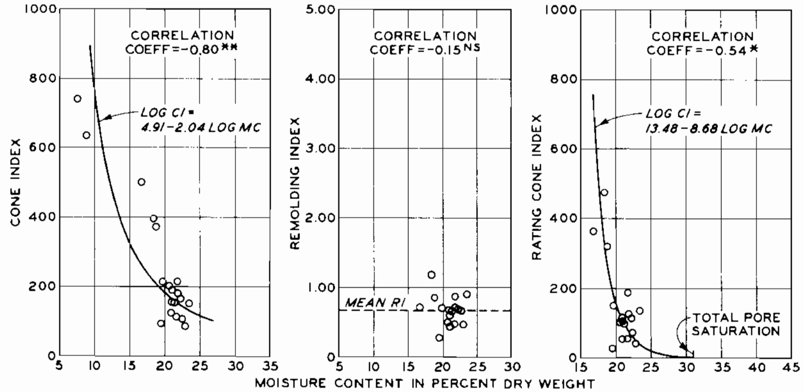


b. HAT YAI AREA

SCHEMATIC TRANSECTIONS

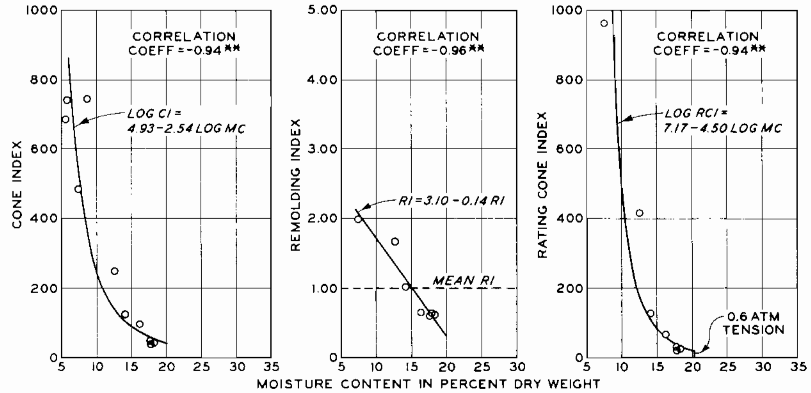
CHANTHABURI AND HAT YAI
STUDY AREAS

PLATE 4



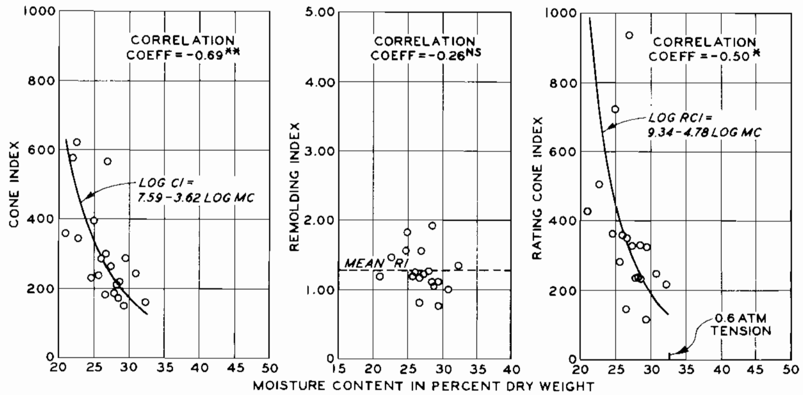
SITE PD 241

LOW HUMIC GLEY SOIL ON LOWER TERRACE



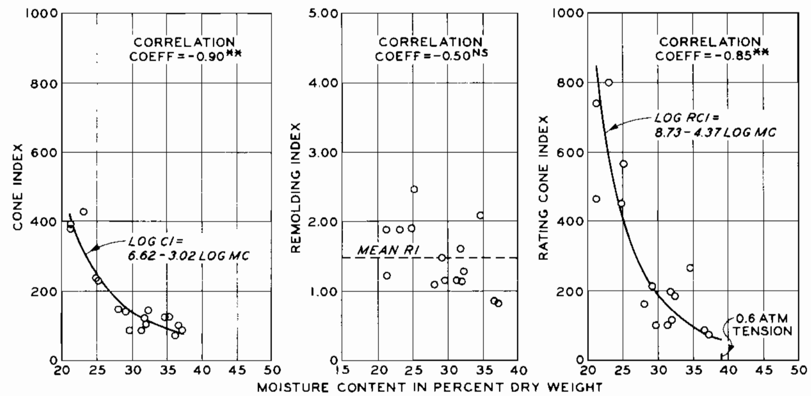
SITE TS 31

GRAY PODZOLIC SOIL ON MIDDLE TERRACE



SITE TS 47

REDDISH-BROWN LATERITIC SOIL ON HILLS



SITE TS 3

RED-YELLOW PODZOLIC SOIL ON MOUNTAIN RIDGE

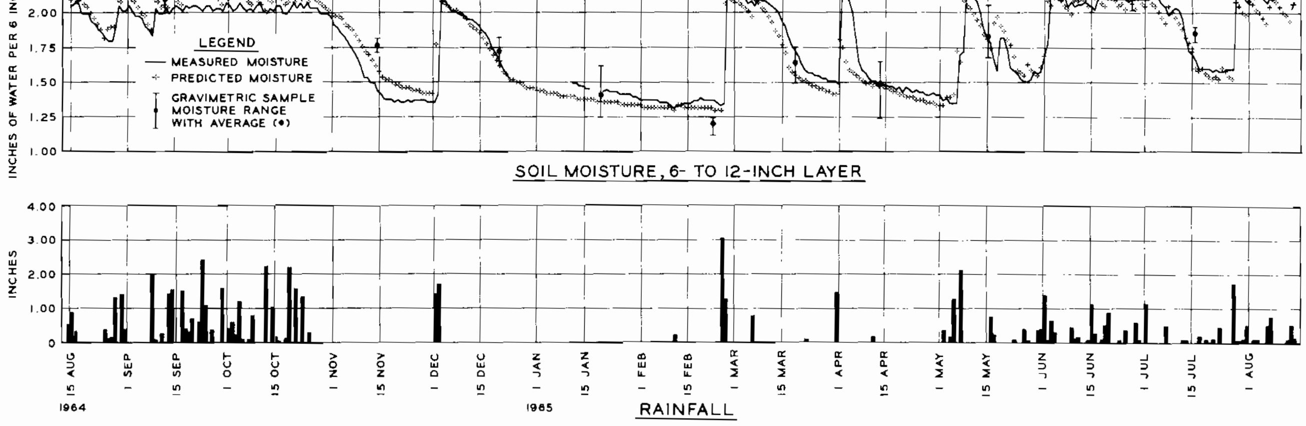
NOTE: PLOTTED POINTS ARE FROM TABLE II - 1.
FOR ADDITIONAL SOIL AND SITE DATA SEE TABLES 1 AND 2.

CORRELATION SIGNIFICANCE

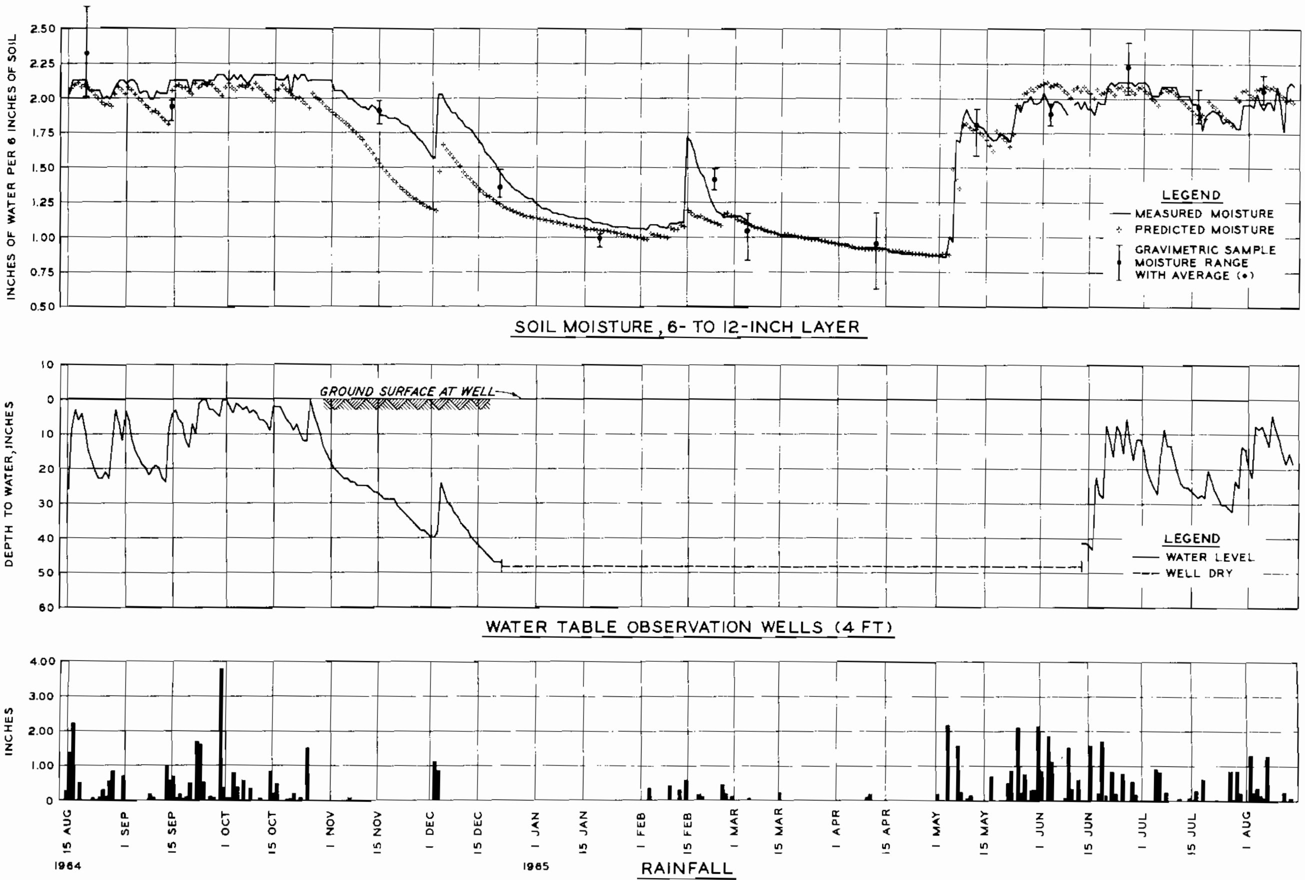
** HIGHLY SIGNIFICANT - ≤ 1% LEVEL
* SIGNIFICANT - 1 TO 5% LEVEL
NS NOT SIGNIFICANT - > 5% LEVEL

SOIL STRENGTH-MOISTURE RELATIONS
FOUR SITES

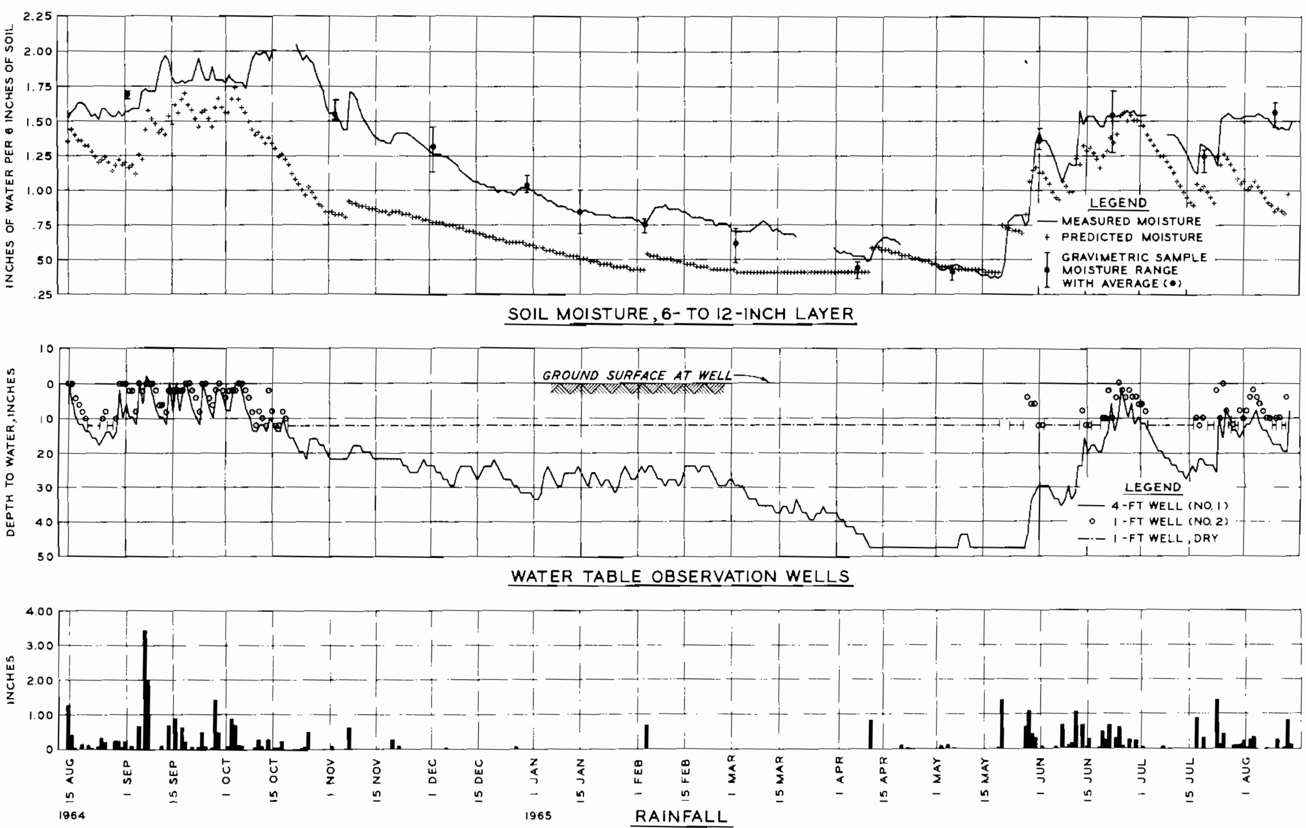
PLATE 5



a. SITE 254, LOP BURI AREA



b. SITE 255, LOP BURI AREA



c. SITE 243, CHIANG MAI AREA

PREDICTED AND MEASURED SOIL-MOISTURE REGIMES

APPENDIX A: THAILAND AND STUDY AREAS

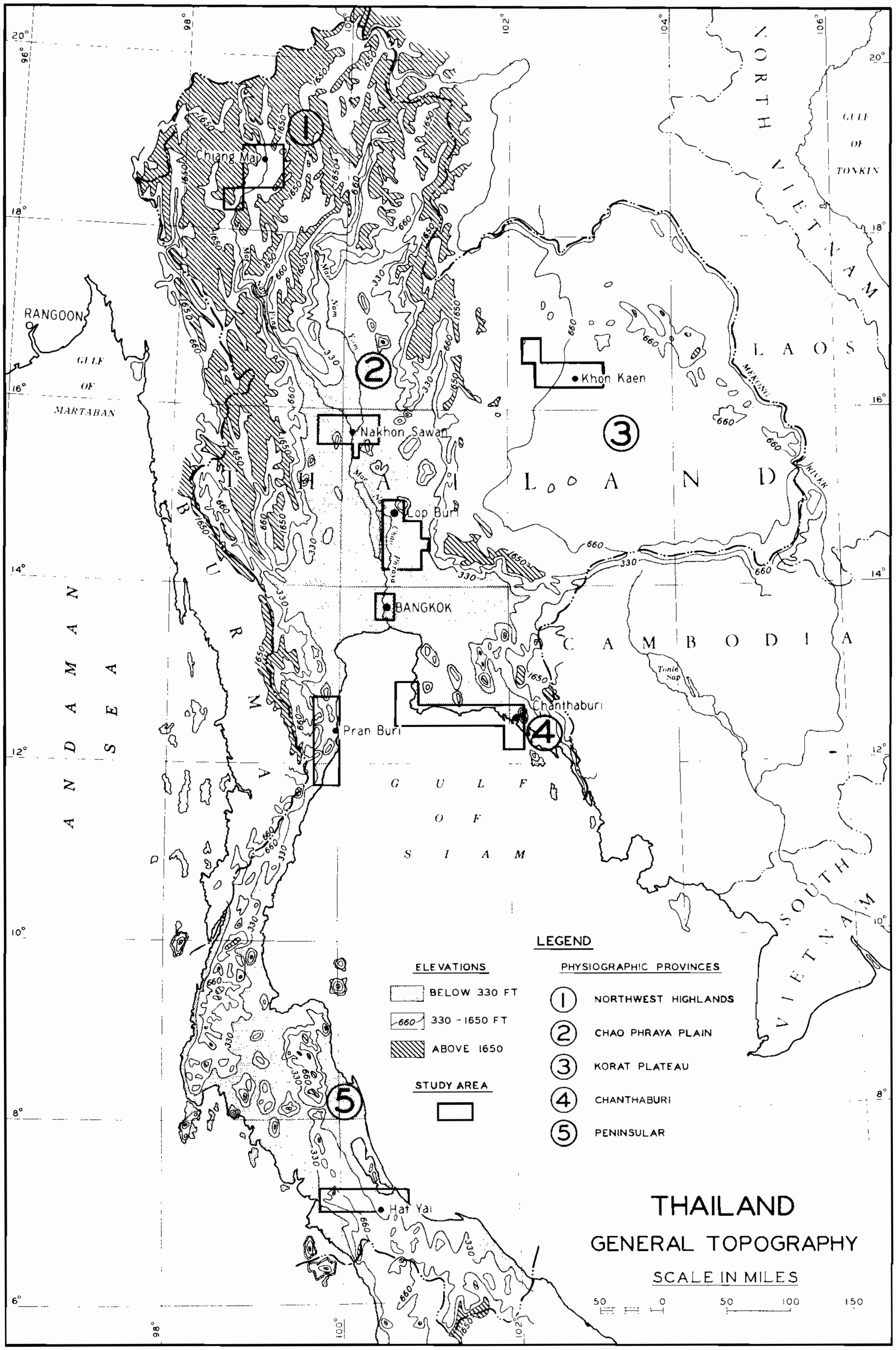


Fig. A1. General topography of Thailand

APPENDIX A: THAILAND AND STUDY AREAS

Thailand

1. Thailand is centrally located in the Indo-Chinese peninsula and is roughly 400 miles square with an extension south for 500 miles down the Malay Peninsula (see fig. A1). Burma is west and north of Thailand; Laos, north and east; and Cambodia, southeast. Malay borders Thailand to the south on the lower peninsula.

Topography and physiography

2. The general topography of Thailand is shown in fig. A1. The contour lines were adapted from two sources.[1,2] For purposes of discussion, the five physiographic provinces recognized by Brown and others[3] are used. The Northwest Highlands consist of parallel mountain ranges 2000 to 5000 ft in elevation, and of intermountain basins connected by narrow valleys. The Highlands extend across northern Thailand and south through the western length of the country. The flat Chao Phraya Plain, less than 300 ft in elevation, occupies the central region. The undulating Korat Plateau, at a general elevation of 500 ft, occupies the northeast region. Drainage of the area is south and east to the Mekong River. Low mountains (2000 to 3000 ft high) separate the Korat Plateau from the Chao Phraya Plain. The Chanthaburi Province in the southeast has dissected uplands that extend east and south to the Chanthaburi[3] and Cardamon Mountains[4] of Cambodia that rise to 5000 ft. The Peninsular Province is an extension of the Northwest Highlands with lower mountains, 1000 to 3000 ft high, fringed by plains between the mountain ridges and along the coast.

Soil parent material

3. The parent material classification of the soils in Thailand, shown in fig. A2, is adapted from Brown and others,[3] Pendleton and Moṭrakun,[5] and from various Thailand Soil Survey Reports by Rojanasoonthon and Moormann.[6,7] Pedological soil identification, classification, and mapping of the study areas also can be found in these reports. Parent materials are divided into six broad groups, each containing a variety of soils:

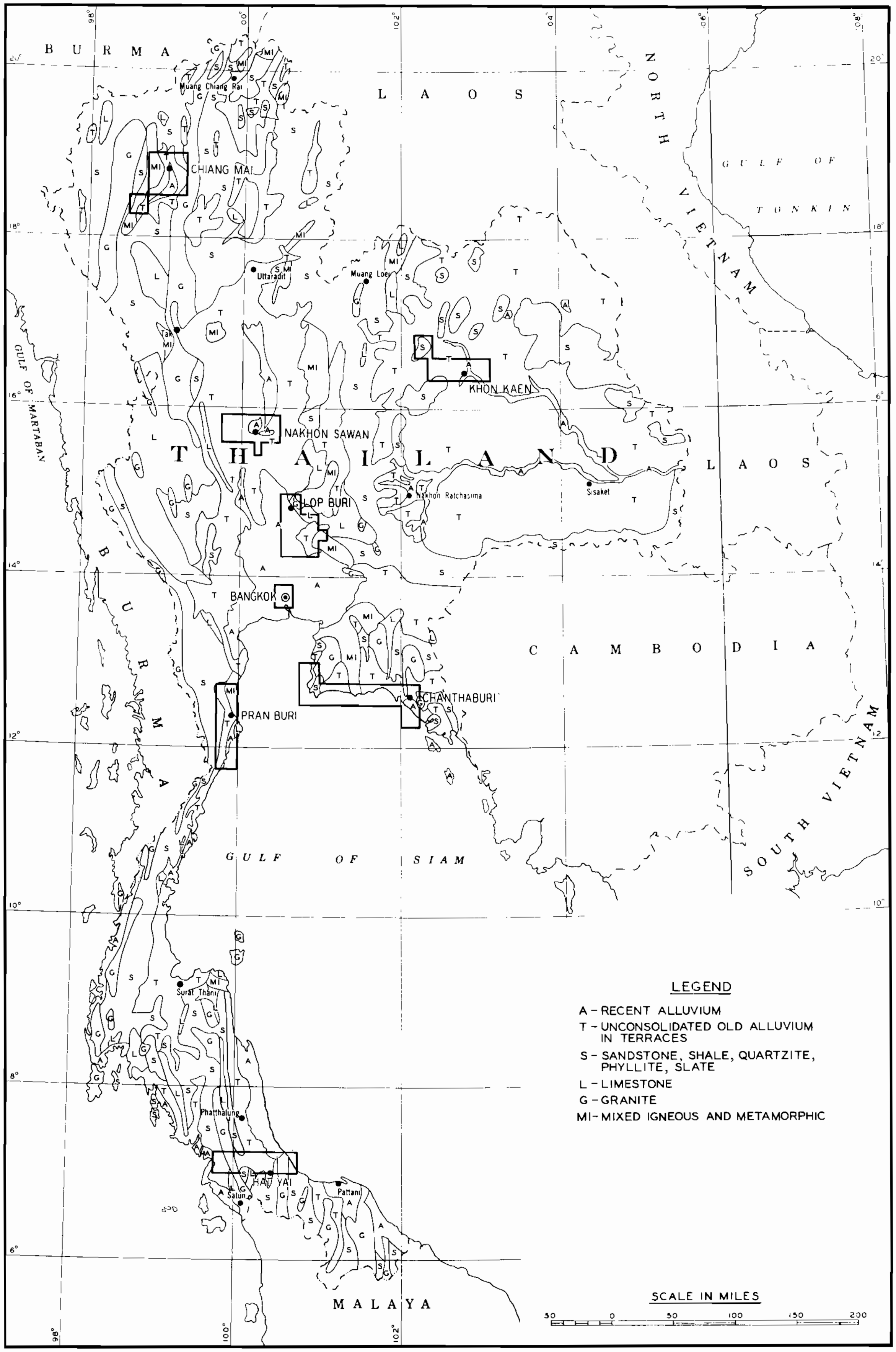


Fig. A2. Soil parent material of Thailand

a. Recent alluvium (A)* is generally fine textured (except natural levees that have medium-to-coarse texture) and may be critically soft if recently or semirecently deposited in lakes or seas.

b. Unconsolidated old alluvium in terraces (T) was deposited and developed in three stages.[8] The high terrace is oldest, most weathered, and generally of sand, sandy loam, or sandy clay texture, well drained, and firm. The middle terrace is often sandy in texture with fair-to-good drainage and is often firm, but areas of fine sands with fines become critically soft when wet. The low terrace has a variety of textures with much fine sand to silt, and frequently has perched water tables near the surface with random depressions that can become critically soft.

c. Sedimentary rocks (S) and their metamorphic equivalents usually develop into sandy or clayey soils, generally firm.

d. Limestone (L) generally develops into fairly firm clayey soils.

e. Granite (G) develops into firm sandy soils.

f. Mixed igneous and metamorphic rocks (MI) develop into a variety of soils, usually coarse textured or clayey, and generally firm.

4. Thailand does not have volcanic ash materials on the surface that give rise to the generally soft Ando soils such as those found in Hawaii; however, these do occur in the Malay Archipelago.

Vegetation

5. The major influence of vegetation on soil moisture and strength is the transpiration process of plants, which causes soil drying. Drainage occurs when free water is present in the soil, and evaporation takes place at the soil surface, but most of the soil water below the surface is removed through the plant roots. Vegetation also has significance in that the amount of vegetation governs the amount of interception of rain, preventing its entry into the soil, which governs the magnitude of the minimum-size storm used in moisture-strength predictions. Another significance of vegetation is that some plants are direct indicators of soil or moisture conditions. For example, in the middle terraces of Thailand, areas with a scattered cover of the small, broad-leaved dipterocarp tree species often have sandy, well-drained soils of the Gray Podzolic or Red-Yellow Podzolic great soil groups. Locations covered with horsetail scouring rush

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* Refer to legend, Fig. A2.

(equisetum) observed in the lower Chao Phraya Plain have soils that are continually wet. Along the coast, coconut groves occupy locations with sandy, well-drained soils. Major plant groupings give general information; for instance, the tropical rain forest grows in continually very wet areas, whereas the tropical deciduous forest grows in less wet areas that have a pronounced dry season.

6. A general map of vegetation, fig. A3, is adapted from Hall.[9] Four groups are shown and are described below.

a. Cultivated areas, including abandoned areas, are extensive and correspond closely to the recent alluvial and terrace soil materials.[4] Some maps show much of this area as dry monsoon forest;[4] other maps show it as savanna.[10] Recent writers consider that these "savanna" areas were originally monsoon forests.[4,11,12] Over the centuries many of the forested lands have been cleared, cultivated, grazed, and repeatedly burned so that lands not currently tilled now support a cover of grass with scattered trees or thickets of bamboo and thornbush. The possibility of regeneration to the monsoon forest vegetation is remote because of impoverished and droughty soils and periodic burning. The lower floodplains, with prolonged, deep flooding, support direct-seeded "floating" rice. Higher floodplains and lower terraces support transplanted rice with the fields having low dikes to retain rainwater. Higher terraces, plateaus, and foothills throughout Thailand support upland tilled crops, grazing, and a variety of shrub and tree crops for food and fiber, with extensive rubber groves in the southern areas. In or near all villages and cities intensive cultivation of vegetable gardens and fruit orchards, including coconut and banana, is practiced on natural river levees and other high ground or on ridges made for this purpose.

b. The tropical evergreen forest occupies the windward (generally westward) slopes of the mountains, higher altitudes of all mountains, and all altitudes of the lower peninsula. Evergreen forest types change at different altitude zones. This group includes some small areas of pine-oak forest in the northern mountains at altitudes of 2000 to 4000 ft.

c. The mixed deciduous forest occurs in the generally noncultivated hills and mountains in areas with a definite dry season. These deciduous forest areas are sometimes subclassified into dry and moist monsoon forests. The dry monsoon forest has a characteristic dwarf dipterocarp tree "only 25 to 45 ft high."[11] This forest is common in the Korat Plateau and upper Chao Phraya Plain and elsewhere in rain shadows on the leeward side of high mountains or on droughty soils. The

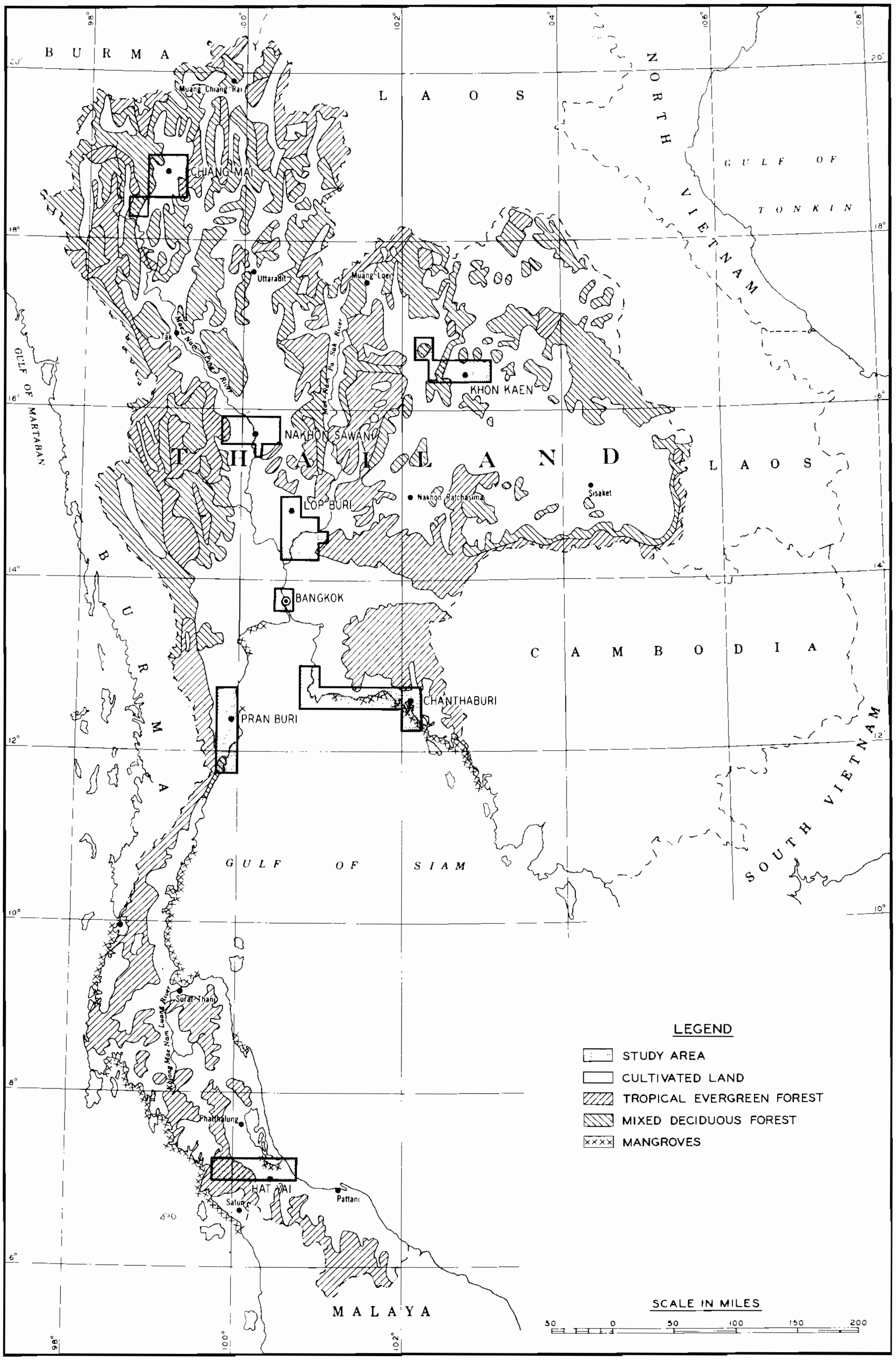

Fig. A3. Vegetation of Thailand

moist monsoon forest has trees taller than 100 ft. Extensive and relatively pure stands of teak occur in this forest type in the northern mountains. Random patches of the more fertile soils in the hill and mountain deciduous forests are subject to periodic burning and cultivation for a few years, and then fallowed for a longer time with formation of secondary forest. Much of the mountain country is subject to uncontrolled fire which escapes from the burning patches. The composition of the secondary forests and the soils can vary from place to place depending on the frequency and intensity of the cultural disturbance.

d. Mangrove swamps occur along the submerged coasts, particularly south of Chanthaburi and along the western coast of the lower peninsula.

Climate

7. The weather modifies the moisture content of the soil, and thereby the soil strength, and therefore has an important influence on trafficability. Both accretion and depletion of soil moisture are affected by the weather.

8. Rainfall. Rainfall is generally the primary source of water for accretion. A map showing lines of equal annual rainfall from a 34-yr record[13] (fig. A4) shows that most of Thailand receives from 40 to 60 in. of rainfall a year. Higher amounts of rainfall (above 100 in.) occur to the west of the higher mountain masses and across the lower peninsula. A map of the 1951-1960 period, by Sternstein,[14] agrees closely with the older map referenced above.

9. The rainy season occurs from May through October, due to the southwest monsoons, with highest amounts of rainfall from August to October; the low rain period occurs from December to March. Exceptions to the general pattern exist. At Sattahip, in the western part of the Chanthaburi area, a distinct second period of high rainfall occurs in April and May. Chanthaburi is marked by very high rainfall amounts throughout the rainy season, and a shorter dry season than most of Thailand. At Songkhla, in the lower peninsula, the peak of the rainy season occurs from October to January, due to the northeast monsoons, with no marked dry season.

10. Air temperature. On an annual basis, the temperature regimes are very consistent throughout Thailand, with slight lowerings of some values in northern and coastal locations. Monthly maps (fig. A5), however, show

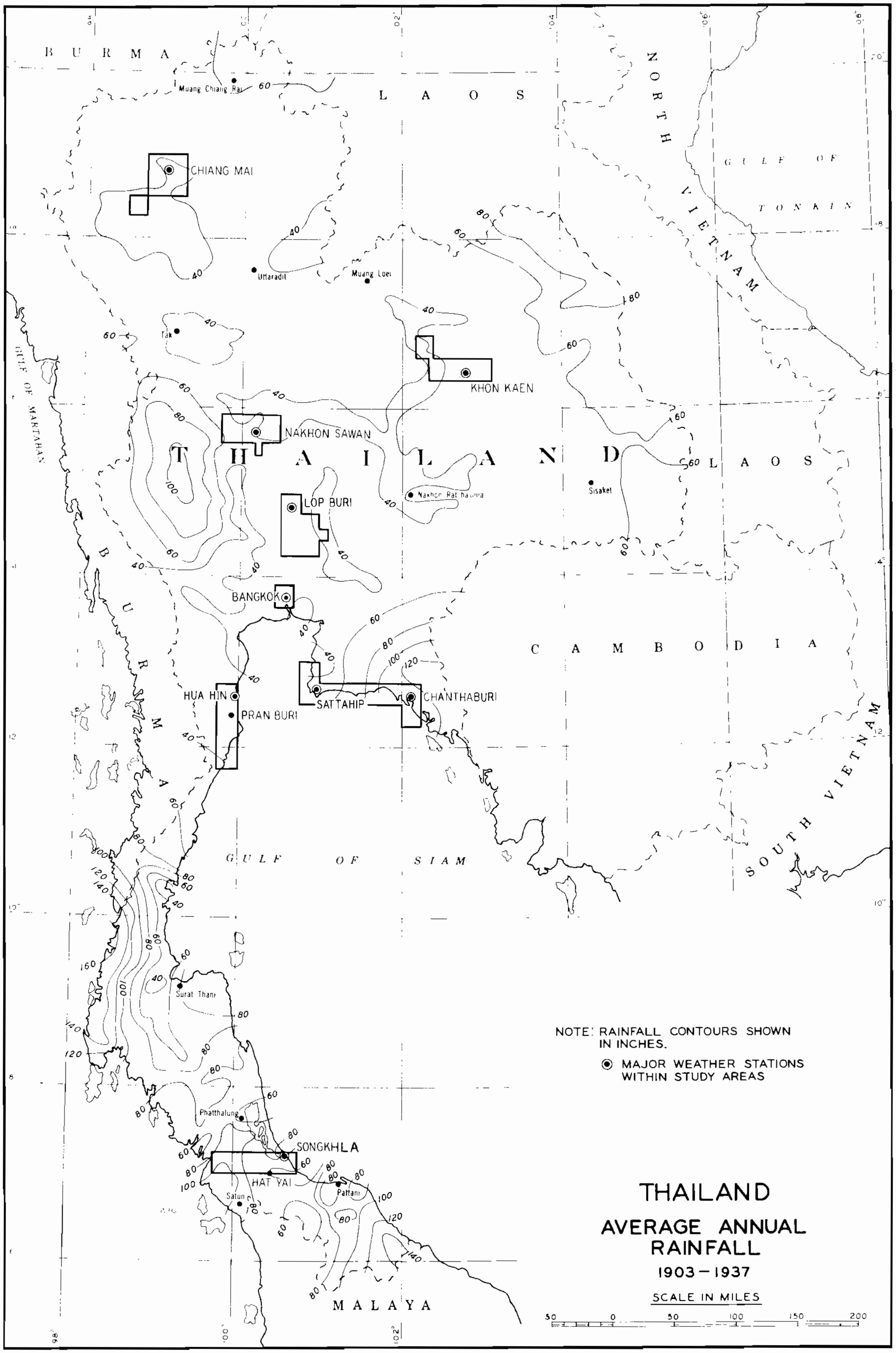

Fig. A4. Average annual rainfall in Thailand, 1903-1937

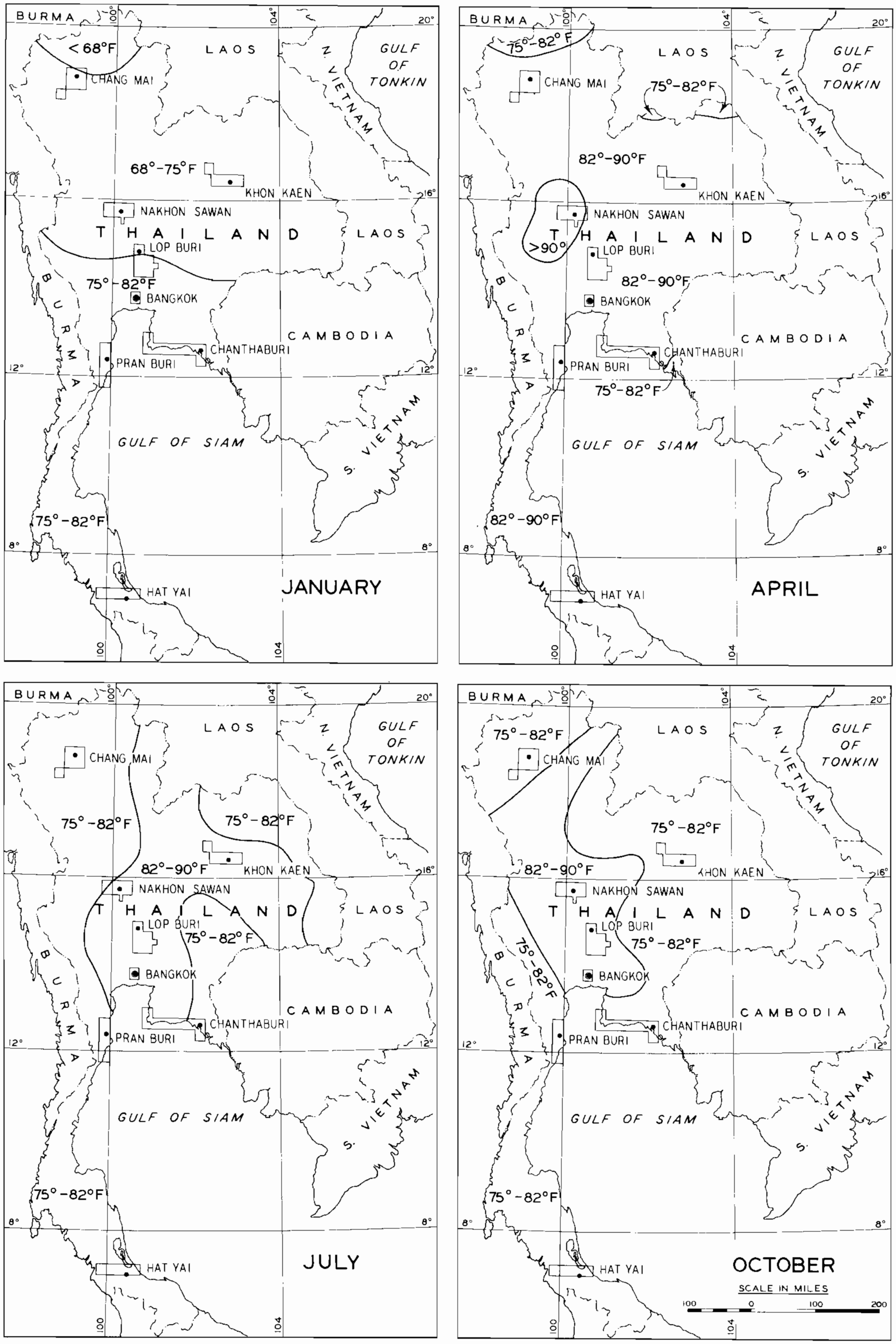

Fig. A5. Mean monthly air temperatures in Thailand areal differences not apparent in the annual values.

Chiang Mai Study Area

Topography and physiography

11. The Chiang Mai study area, located in the Northwest Highlands, is an intermountain basin of 1000-ft elevation, drained to the south by the Ping River. The basin is roughly 15 miles wide and 30 miles long and is bordered on the west by a series of steep mountain ranges that rise 3000 to 5000 ft. From the foot of the mountains to the river, the terrain descends in steps that usually represent terrace remnants of different ages.[6] The older terraces are dissected, with undulating to rolling terrain; the lower, younger ones are relatively flat. The mountain ranges converge north and south of the basin.

Soil parent material

12. The area is largely covered by recent alluvium and terrace sediments, with a granite mountain range to the east and mountains of gneiss and schist to the west. Sandstones and shale occur in the northeast sector.

Vegetation

13. In the Chiang Mai basin, the Ping River alluvial plain and lower terraces are cultivated. Extensive areas are irrigated during the dry season and have two crops a year. This practice can produce soft soils in irrigated fields, with firm soils in surrounding fallowed fields. The dominant crop is rice; peanuts, soybeans, tobacco, and other field, vegetable, and fruit crops including strawberries also are grown. Mixed deciduous forests are generally found on the higher terraces, foothills, and mountains, with some pine-oak forests at higher elevations in the western mountains of the area.

Khon Kaen Study Area

Topography and physiography

14. The Khon Kaen study area is near the center of the Korat Plateau,

and is characteristic of this region with relief differences of 100 ft on the undulating terrain; numerous meandering and entrenched rivers; abandoned river channels with lakes; and occasional hills, some of which rise like mesas 1000 ft above the surrounding terrain.

Soil parent material

15. The area is largely covered by the three terrace formations, with recent alluvium along the rivers, abandoned channels, and lakes, and sandstone and conglomerates in the mesas and protruding hill masses.

Vegetation

16. The Khon Kaen area is generally cultivated, grazed, or fallowed. The hills support shrubs or a poor growth of the dwarf dipterocarp type of mixed deciduous forest. Marsh vegetation grows around lakes and in low spots.

Nakhon Sawan Study Area

Topography and physiography

17. The Nakhon Sawan study area has an elevation of about 70 ft and is located near the center of the Chao Phraya Plain, at the junction of the Ping and Nan Rivers, where they form the 150-mile-long Chao Phraya River. All drain south. The terrain is generally flat with a gentle slope upward from the river plain through terraces and across low plateaus. Occasional hills and ridges, oriented north-south, rise abruptly 500 ft above the level terrain. A large lake is located east of Nakhon Sawan.

Soil parent material

18. Low terrace sediments cover most of the area, with recent alluvium along the rivers, abandoned channels, and lakes. Plateaus and buttes, and ridges that protrude through the plain are composed of limestone, granite, gneiss, and schist, or mixed sedimentaries, indicating the complexity of the geology. The hills, 1 to 2 miles wide and from 1 to several miles long, are too small to portray in fig. A2.

Vegetation

19. The Nakhon Sawan area is largely cultivated in rice fields, reflecting the extensive areas of river floodplain and low terrace. Higher terraces and plateaus support tilled crops, such as corn, or are fallowed.

Scattered secondary forests and shrubs are found here and in the low hills. Higher hills support the mixed deciduous forests.

Lop Buri Study Area

Topography and physiography

20. The Lop Buri study area lies mostly within the Chao Phraya Plain, 70 to 100 miles from the Gulf of Siam. The area is 10 to 20 ft above sea level in the flat west and south portions, and rises gently to the east and north through terraces and plateaus 100 to 200 ft in elevation, where numerous hills rise abruptly 500 to 1000 ft above the gently sloping terrain. The eastern projection of the area grades into the foothills of the mountains that separate the plain from the Korat Plateau.

Soil parent material

21. The area is similar to that of Nakhon Sawan, except that the hill areas of a given parent material are larger. Half the Lop Buri area is recent river alluvium and lake sediments, with semirecent marine sediments to the southeast. An extensive low terrace formation exists. The hills and mountains include andesite, granite, and limestone, and a limestone plateau occurs amid the limestone hills.

Vegetation

22. The vegetation in the Lop Buri area is similar to that in the Nakhon Sawan area, with areas of higher terrace and plateau that support tilled crops, including corn. Grazing areas are larger than those at Nakhon Sawan. Areas of high hills support mixed deciduous forests and are more extensive than in the Nakhon Sawan area.

Bangkok Study Area

Topography and physiography

23. The Bangkok study area is in the lower Chao Phraya Plain, 15 miles from the river mouth. The terrain is flat with no hills, 5 to 10 ft above sea level, and contains many irrigation canals and ditches and man-made ridges about 20 ft wide in the western part of the area, used locally for

intensive fruit and vegetable cultivation.

Soil parent material

24. The entire area is recent alluvium and marine sediments.

Vegetation

25. In the Bangkok area, beyond the extensive urban area, rice cultivation is dominant to the east and north. A continuous area west and south of the Chao Phraya River is covered with the ridge-ditch configurations used for intensive production of vegetables and fruits, including coconut.

Pran Buri Study Area

Topography and physiography

26. The Pran Buri study area, located in the north of the Peninsular Province, is a generally flat to gently undulating terrace at an elevation of about 200 ft with a moderate downward gradient to the east coast. Two lines of hills with a north-south trend are in the area. One, about 12 miles west of the coast, rises 600 to 1300 ft as rounded hills with moderately steep slopes and is part of the extensive mountain ranges farther west; the second angles to the coast at Hua Hin, 10 miles north of Pran Buri, and follows the coast southward, increasing in steepness and elevation from 1000 to 2000 ft. Smaller hills are scattered between the hill ranges. The Pran Buri River, with a narrow floodplain, flows in an easterly direction through the center of the study area.

Soil parent material

27. The area is largely composed of terraced marine sediments north of the Pran Buri River, and alluvial fan-apron sediments south of the river. These later sediments were washed in from the quartzite-phyllite metamorphosed rock from the hills and mountains to the west. The coastal hills are gneiss in the north, and limestone in the south. A large depression with recent marine and local alluvial sediments occurs south of Pran Buri and west of the limestone hills.

Vegetation

28. The vegetation of the Pran Buri study area resembles that of the

upper Chao Phraya Plain, with rice in the lowlands, tilled crops in the higher terraces, shrubs and grasses in the fallow areas, and mixed deciduous forests in the hills. However, the shrubs are impoverished and the grass scanty, reflecting the low annual rainfall of this area. Pineapple is one of the principal tilled crops. Thickets of bamboo and thorn shrubs occur. Steep hills have rock outcrops, bare of vegetation. Following burning and cultivation the regeneration of forests on slopes and hills was poor or failed, and the vegetation remains shrubs and grasses. Beach dunes and the wash-over apron landward from the dunes have scattered low shrubs, cacti, and sparse grass. The large relic lagoon south of Pran Buri is covered with marsh grasses and rushes.

Chanthaburi Study Area

Topography and physiography

29. The Chanthaburi study area stretches along much of the southeast coast, a distance of 90 miles, as an undulating to rolling coastal plain with elevations to 200 ft. Chains of hills and mountains, spaced roughly 12 miles apart, extend south to the coast and show in places as islands in the Gulf of Siam. The hills are steep and rise to 300 ft at Sattahip in the west, and to 5000 ft east of Chanthaburi. River plains extend north of Rayong, near the center of the area, and northeast of Chanthaburi. Extensive marshes occur south of Chanthaburi.

Soil parent material

30. Terraces of old alluvium are dominant parent materials in this area. The older terrace materials have a medium-coarse texture in the western half, but a fine texture is more common in the east at Chanthaburi. The lower terrace has a fine-to-medium texture and occurs along the river valleys. North-south oriented lines of hills and mountains that cross the terrace plain at regular intervals differ in rock type, as in other areas. Around Sattahip, at the west corner, a complex of quartzite, phyllite, and shale hills occurs with some limestone. Two lines of low granite hills outcrop between Sattahip and Rayong, 25 miles to the east. East of Rayong, two lines of gneiss hills occur, one of them massive and rising to 2000 ft.

Farther east, another hill line of quartzite-phyllite occurs. North and east of Chanthaburi separate granite ranges occur. A basalt plateau with an extinct volcanic cone occurs between Chanthaburi and Tha Mai, 7 miles to the west. Recent river alluvium occurs in the river valleys, above Rayong and Chanthaburi. A fringe of sand beaches occurs along the coast of the west half of the area whereas mixed alluvial and marine sediments, usually fine textured and continually wet, fringe the east coast. An extensive area of the mixed sediments, 5 miles wide and extending more than 25 miles along the coast, occurs south of Chanthaburi.

Vegetation

31. The western part of the Chanthaburi area resembles somewhat the Pran Buri area; the eastern part has moist, mixed deciduous forests and changes to the wet tropical evergreen forests near and on the mountains east of Chanthaburi. Most of the study area was under cultivation. Some areas of rice occur generally in the floodplains and low terraces of the few river valleys. Cassava (tapioca) is a principal upland crop in the western part; rubber and fruit groves, including citrus, and black pepper are grown in the eastern part. The hill ranges that extend down to the coast generally support a mixed deciduous forest; mangrove swamps and marshes with grass and rushes are extensive in a broad belt along the coast to the east. The sandy beaches and dune areas on the west support sparse shrubs and cacti.

Hat Yai Study Area

Topography and physiography

32. The Hat Yai study area is located in the southern part of the Peninsular Province, near the Malaya border. Mountains, rising 1200 to 3000 ft with steep slopes, extend south through the center of the peninsula. East of the mountains, a dissected rolling plateau 250 ft in elevation grades downward into a system of undulating-to-flat terraces that extend 30 miles to the east coast. Isolated hills and hill ranges rise from the plain to heights of 600 to 1000 ft. Two major hill lines extend southward between Hat Yai and the coast. A large saltwater lagoon is located in the

northeast section of the area. Small rivers drain east and north. The area west of the main mountain range, with a limited coastal plain and submerged coastline, was not included in the tests.

Soil parent material

33. The area tested is largely covered by terrace materials. Three stages are recognized here, as in most of the study areas. The higher terraces are coarse-to-medium textured; the lower terraces are usually medium-to-fine textured. Isolated hills of limestone and quartzite-phyllite project through the terrace plain. Two ranges of hills, quartzite-phyllite and granite, separated and surrounded by terrace materials, occur east of Hat Yai. Massive granite mountains lie west of the terrace, followed by other massive ranges of quartzite-phyllite and limestone. Clayey marine sediments occur around the lagoon in the northeast sector. Alternating strips of beach sand in ridges and fine-textured alluvium in the depressions occur along the coast.

Vegetation

34. The Hat Yai area supports tropical evergreen forest. Except for the scattered hills throughout the area and the mountain ranges east of Hat Yai, the area east of the mid-peninsula mountain range had been cleared and cultivated at some time. The lower terraces and recent coastal plain, where they are not too salty or too acid, are used for rice cultivation. Higher terraces support rubber groves. The hills and mountains are covered with lush tropical evergreen forests. Mangroves border the lagoon in the northeastern part of the area and also are found along the west coast.

Climate of Study Areas

Rainfall

35. All study areas contain sections with less than 40-in. annual rainfall except the Hat Yai area, where annual rainfall is 60 to 100 in. In fig. A6, the average long-term monthly rainfall amounts[15] for the major weather stations in each study area are compared to the monthly sums of the same stations for the year of this study.

36. The distribution of rainfall by months for the year of record

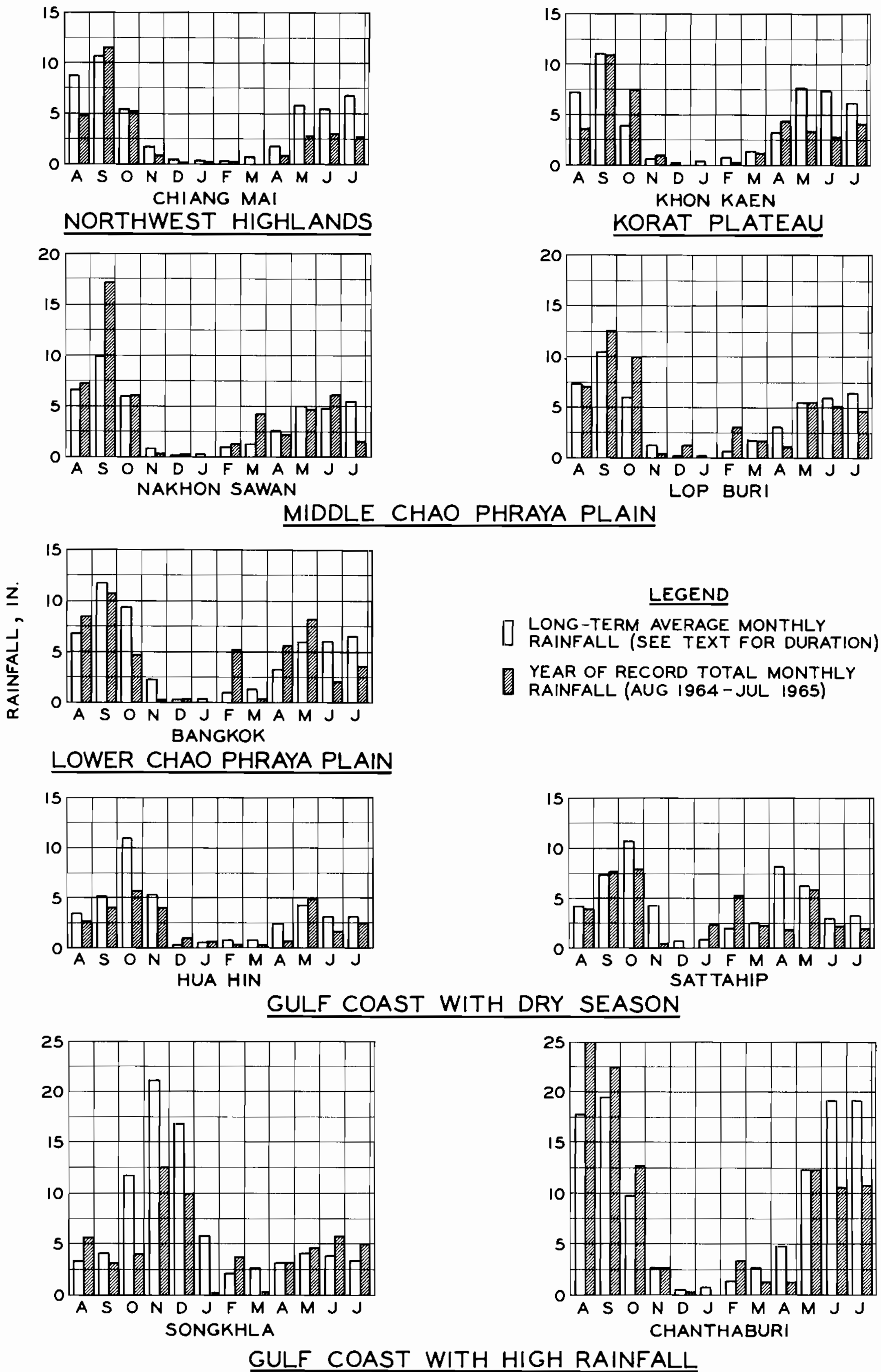

Fig. A6. Monthly rainfall at study areas compares favorably with that of the long-term record for the study areas generally, but the total annual rainfalls for the year of record were drier than average for most areas.

37. The following tabulation shows that the two areas with above-normal rainfall, Nakhon Sawan and Lop Buri, did not have the same wet and dry months; Chiang Mai and Khon Kaen had similar dry months; the other stations show a variety of months, demonstrating a randomness in rainfall pattern.

Area Station	Length Long-Term Record Years	Total Annual Rainfall, in. Long-Term Avg	Year of Record	Difference for Year of Record %	Period of Record Dry* Months	Wet** Months
Chiang Mai	48	48.0	32.3	-33	Aug, May, June, July	--
Khon Kaen	47	49.5	38.6	-22	Aug, May, June, July	Oct
Nakhon Sawan	43	43.8	51.1	+17	July	Sept, Mar
Lop Buri	50	48.8	52.4	+7	Apr	Sept, Oct, Feb
Bangkok	50	55.3	49.5	-10	Oct, Nov, June, July	Feb, Apr, May
Hua Hin	18	40.6	28.1	-31	Oct	--
Sattahip	23	53.3	41.6	-22	Oct, Nov, Apr	Feb
Chanthaburi	50	110.3	102.4	-7	Apr, June, July	Aug, Sept, Oct, Feb
Songkhla	48	82.4	58.1	-30	Oct, Nov, Dec, Jan, Mar	Aug

* Month with total rainfall at least 2 in. less than average.
** Month with total rainfall at least 2 in. more than average.

Air temperatures

38. The average annual maximum and minimum temperatures over a 10-yr period[16] for the main weather stations in the study areas are listed in the following tabulation:

Station	Temperature, °F Maximum	Minimum	Mean
Chiang Mai	90	67	79
Khon Kaen		Not available	
Nakhon Sawan	93	73	83
Lop Buri	92	73	83
Bangkok	91	74	83
Hua Hin	89	73	81
Sattahip	92	76	84
Chanthaburi	90	72	81
Songkhla	89	75	82

39. The daily maximum and minimum temperatures, averaged by months

for a 10-yr period[16] for the major weather stations in each study area, are compared to the averages of the same stations for 1964-1965 in fig. A7. The long-term record exhibits three general trends: The monsoon period from May to November is quite consistent throughout Thailand, with maximum temperatures about 90 F and minimum about 75 F. The winter period, from November to February, has lower temperatures, particularly of the minima. It is noteworthy that definite seasonal temperatures occur so close to the equator (12° latitude). The last half of the dry season (February to May) has high temperatures, particularly of the maxima which in many areas exceed 90 F. The average daily temperature range from December to April is greatest at Chiang Mai and decreases going south. At Songkhla, there is a dip of the maxima during the winter, but the constant minima of 75 F throughout the year is remarkable.

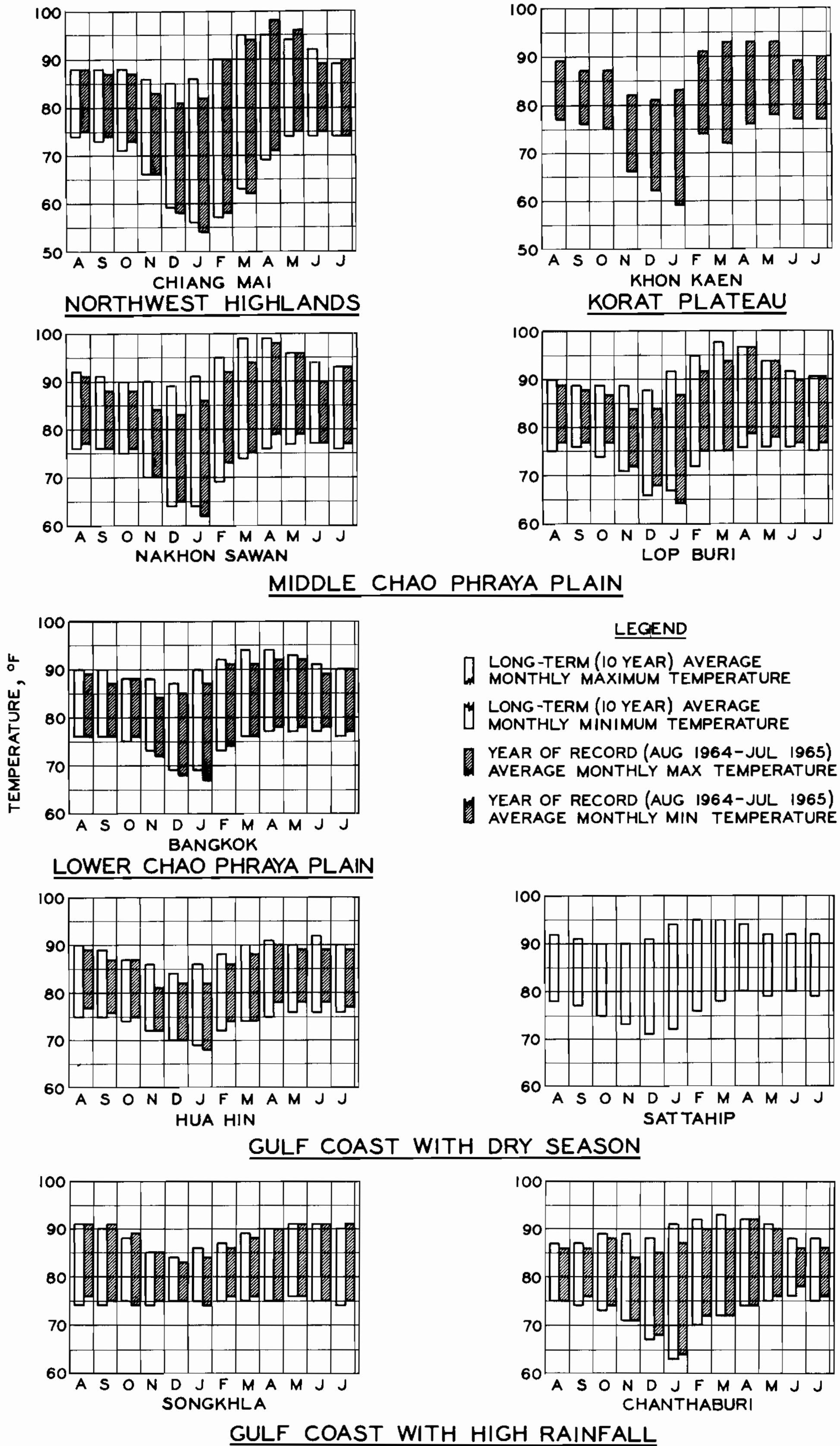

Fig. A7. Monthly air temperatures at study areas

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APPENDIX B: GENERAL SOIL AND MOISTURE CONDITIONS OF SOUTH VIETNAM

1. The purpose of this appendix is to depict in map form the soil and moisture conditions in the 6- to 12-in. layer for broad classes of soils in South Vietnam. The large fluctuations of the 0- to 6-in. layer have been ignored, and the more uniform trends of the 6- to 12-in. layer summarized. Data for deeper layers were not available, but moisture conditions for depths of 5 to 7 ft can be extrapolated from the 6- to 12-in. results if it is recognized that the rate of change and the amount of drying diminish with depth.

Derivation of Map

2. Direct soil-moisture measurements were not available for South Vietnam; however, considerable testing had been performed in nearby Thailand on analogous soils under weather conditions similar to those in South Vietnam, as reported herein and by Rula.[1] The soil-moisture data obtained from these tests have been partially summarized by soil and terrain type for wet and dry seasons. Considerable pedological soil mapping also has been done in Thailand.[2,3]

3. Moormann[4] has described the major soils of South Vietnam and classified them by pedological great soil groups. An accompanying schematic map of the soil regions of South Vietnam provided the basis for assigning soil moisture values, assuming that soil conditions between corresponding great soil groups of the two countries are similar. Approximations of the average durations of the wet season by regions within South Vietnam were made from limited climatological data and notes.[5,6] For this appendix, a month was considered wet when the mean monthly rainfall exceeded 4 in.

Map Contents

4. The map is shown in fig. B1; the legend and explanatory notes

are listed in table B1. The map unit codes are given by number in column 1 and range from water-logged to well-drained soil. In column 2, the theoretical field-maximum moisture contents are expressed as percent by volume of the dominant great soil group of each map unit, and are averages of data from various test sites located on similar great soil groups in Thailand. The theoretical moisture content represents total pore saturation for soils with water tables that rise to the surface; for well-drained soils, it represents the wettest condition that occurs in conjunction with heavy rains that completely wet the soil to a depth of 4 ft or more. The latter moisture condition is approximated by the 0.06-atm soil moisture tension value for the drained soils with water tables that do not come within 4 ft of the surface. The average range of soil moisture contents during the wet season is given in column 3, and the average range during the dry season in column 4. Values were taken from periodic measurements at each test site in Thailand, then averaged by sites for the same soil groups used in column 2. The dominant pedological great soil groups as classified by Moormann[2,4] are listed in column 5; the general soil materials in column 6; and common landform occurrences in column 7.

Explanation of Map Units

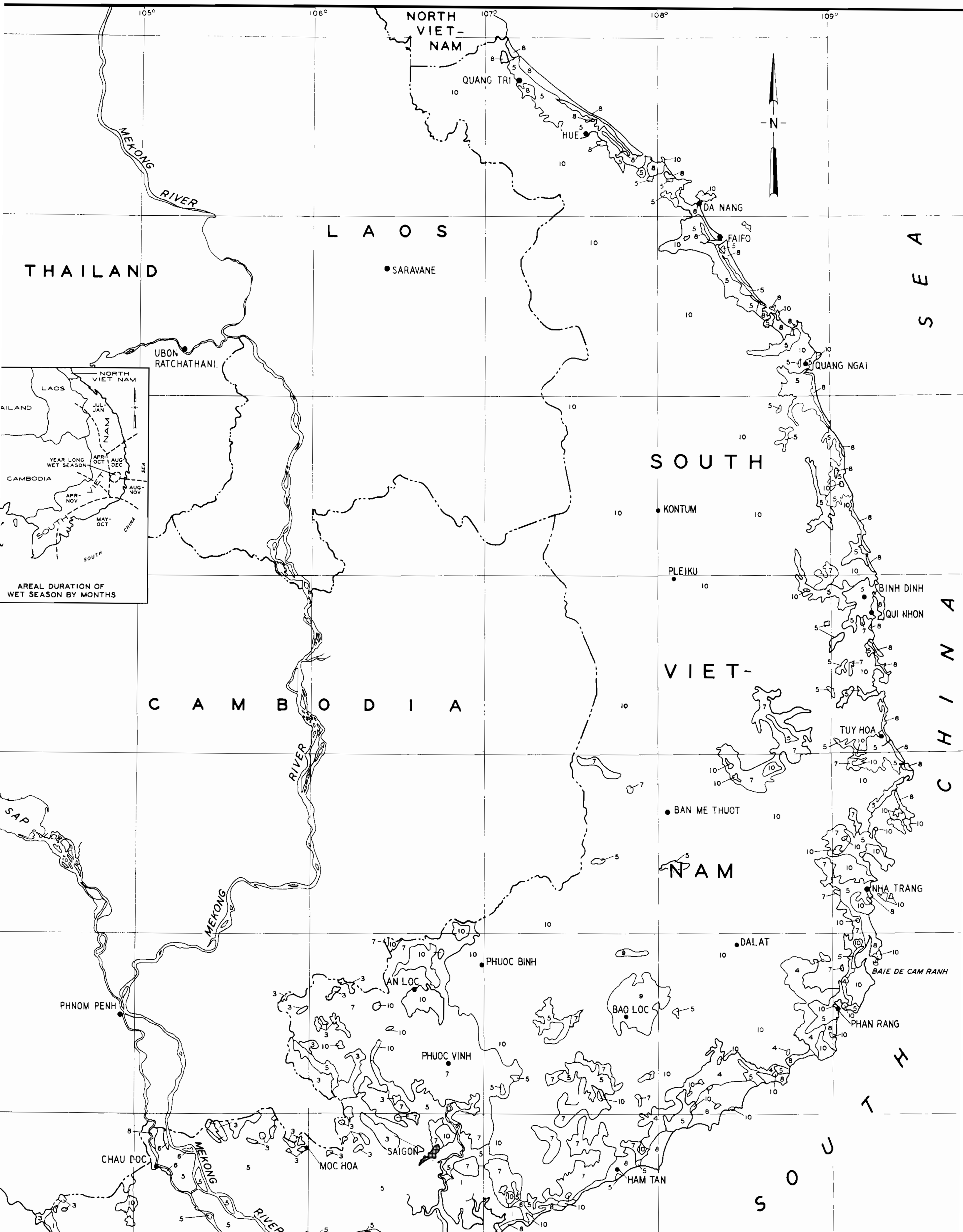
Qualifications

5. It should be emphasized that the map units are based on a generalized soil map of South Vietnam that was made primarily from semi-detailed and reconnaissance soil surveys and are meant to give only the dominant soil and moisture conditions to be expected in an area.

6. Appreciable portions of some of the map units may contain inclusions of varied materials with moisture contents different from that of the dominant material. In addition, the duration of the wet season can be expected to change from year to year; and in a given area, a wet season can be interrupted by a dry month, or an extensive rainy period during the nominal dry season can produce wet soil conditions.

Description of map units

7. Unit 1. This unit is generally uniform, comprised of marine



LEGEND

MAP UNIT CODE	THEORETICAL AVERAGE FIELD-MAXIMUM SOIL MOISTURE CONTENT, % BY VOLUME	AVERAGE SOIL MOISTURE RANGE, % BY VOLUME	
		WET SEASON	DRY SEASO
1	69.0	45.8-69.0	33.8-45.8
2	72.1	68.9-72.1	53.9-68.9
3	42.3	23.6-32.7	11.8-23.2
4	42.8	17.0-30.8	10.0-17.0
5	46.3	29.3-38.4	18.5-30.4
6	36.3	14.0-30.4	7.9-14.0
7	31.9	15.7-26.8	8.2-15.4
8	34.0	14.3-30.8	5.4-14.2
9	47.0	29.1-43.3	23.6-28.5
10	39.2	24.2-33.1	16.0-24.1

clays, but a few inclusions of sandy Regosols (unit 8) are found. The clays are plastic and cohesive, with high moisture content. The moisture ranges given in the legend apply to the higher border areas surrounding the marshes and mangrove swamps which are generally saturated throughout the year.

8. Unit 2. Organic soils of this unit are quite uniform and contain few or no inclusions. They are generally at or near saturation throughout the year unless artificially drained. Small areas of these materials occupy poorly drained depressions everywhere in the country and are inclusions within other map units.

9. Unit 3. The Low-Humic Gley soils of this unit generally consist of sandy or silty materials overlying clays. A layer of low permeability, generally occurring at a depth of 11 to 27 in., impedes drainage and causes perched water tables to form above the layer following moderate rainfall. During rainy periods in the dry season, and at the start of the wet season, the surface layers may become saturated, while the soil beneath the low-permeable layer may remain relatively dry. As the wet season progresses, the permanent water table gradually rises and blends with the perched water table. The water table may then remain near the surface for an extended period, depending on the rainfall pattern and the terrain configuration. With the advent of the dry season, soils with high water tables dry more slowly than well-drained soils with no water table near the surface, and may remain moist for 2 to 4 weeks longer, but all soils attain the same relative dryness after 6 to 8 weeks. Minor inclusions of Alluvial soils (unit 5) and Gray Podzolic soils (unit 7) are found in this unit. These latter soils have no perched water tables but may have high permanent water tables during the wet season.

10. Unit 4. This unit includes moderately weathered materials in low rainfall areas. Medium-textured materials with high moisture capacity are usually found near the coast, and sandy-textured materials with low moisture capacity toward the mountains. Soils in this unit are well drained, with no water tables. Minor inclusions are wetter Alluvial soils (unit 5) and low-water-content Lithosols and Red-Yellow Podzolics near rock outcrops (unit 10).

11. Unit 5. The Alluvial soils included in this group are quite variable. Near the coast and in broad valleys, the materials are dominantly clays, including old marine clays and more recent backswamps, but also include narrow strips of sandy Regosols (unit 8). Water tables, which fluctuate, remain near the surface during extended rainy periods; during the dry season they recede well below 4 ft and surface layers dry, producing large, deep cracks. In smaller valleys, the materials are variable--sand, silts, and clays--with fluctuating water tables that are near the surface in the wet season only. Inclusions of older alluvium (unit 7) also occur in the smaller valleys.

12. Unit 6. These Alluvial soils, occurring in natural levees, are better drained and generally drier than adjacent Alluvial soils (unit 5), strips of which may be inclusions of this map unit. Medium- and fine-textured materials have higher moisture contents than coarse materials, and water tables generally are deep.

13. Unit 7. The dominant Gray Podzolic soils of unit 7 are generally well drained with no water tables, but the unit is a complex with many inclusions. Depressions with Low-Humic Gleys (unit 3) and Alluvial soils (unit 5) comprise approximately 15% of the total area; an additional 15% consists of medium-textured sand with fines, poorly drained, that contribute to high moisture contents. Inclusions of Latosols, Grumusols, Red-Yellow Podzolics, and transitions to Noncalcic Brown soils also occur.

14. Unit 8. Soils in this unit are nonplastic, coarse-textured, well-drained sands, with no water tables that dry quickly between rains. Low areas containing sand with fines and organic matter and inclusions of Alluvial soils (unit 5) are wetter and may have periodic water tables following sufficient rainfall. Inclusions of Red-Yellow Podzolic soils (unit 10) occur.

15. Unit 9. This unit includes the Reddish-Brown Latosols of basalt plateaus and inclusions of the wetter Alluvial soils of the broad valleys (unit 5) which could not be mapped separately. The Latosols are well drained and have no water table, while the Alluvial soils of the valleys may reach saturation. Slopes have inclusions of Lithosols and Red-Yellow Podzolic soils (unit 10).

16. Unit 10. This unit is a complex of many soils found in the plateaus and mountains, primarily Red-Yellow Podzolic soils, Red-Yellow and Reddish-Brown Latosols, and Lithosols. Dominant materials are clays of low plasticity, sometimes with sand, hard laterite, and rocks. The soils generally have good surface and internal drainage with no water tables, and dry quickly between rains. Inclusions of variable textures and higher moisture contents are found in some depressions and along generally narrow valleys.

Use of Map

17. Ranges in moisture content in the 6- to 12-in. layer of ten classes of soils can be determined from the map. For example, beyond An Loc, 65 miles north of Saigon, extensive areas of Gray Podzolic soils occur, designated by map unit 7. Based on data in the legend and the inset map showing areal duration of the wet season, moisture content of the soil can be estimated to range from 15.7% to 26.8% by volume from April to November, and from 8.2% to 15.4% from December to March. Allowances must be made for exceptional weather conditions in either season. If estimates are desired of inclusions within the map unit area, and if these can be identified as one of the other map units, the moisture ranges of that included map unit should be used.

18. Assuming that the soil moisture-holding properties do not change with depth and that the soil profile is occupied with plant roots capable of extracting water at the lower depths as well as at the surface, values can be applied to soil depths of 5 to 7 ft. If the lower depths are not sufficiently occupied with plant roots or are below the plant root zone, the high value for the dry season should be used for lower depths, e.g. 15.4% for unit 7.

19. Soils with water tables that rise to the surface become saturated, and the average moisture content for all soil depths then is considered the theoretical maximum as listed in the second column of the legend. Map units 1 and 2 would remain at this value throughout the year except near the soil boundaries or at higher elevated inclusions. Units 3,

5, and possibly some areas of unit 7 would remain at the maximum moisture content during the wet season, except during unseasonal dry spells. Units 3 and 5 moist conditions would extend 2 to 4 weeks into the dry season, due to the influence of the receding water table. During the transition months between seasons, moisture content will depend on whether seasonal rainfall is early or late.

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Table B1

Classes of Soils and Moisture Conditions in South Vietnam

6- to 12-in. Soil Layer

(1) Map Unit Code	(2) Theoretical Average Field-Maximum Soil Moisture Content % by Volume	(3) Average Soil Moisture Range, % by Volume: Wet Season	(4) Dry Season	(5) Great Soil Groups	(6) Materials	(7) Occurrence
1	69.0	45.8-69.0	33.8-45.8	Saline Alluvial	Clays	Tidal marsh and mangrove
2	72.1	68.9-72.1	53.9-68.9	Organic	Peak and muck	Coastal bogs
3	42.3	23.6-32.7	11.8-23.2	Low-Humic Gley	Medium texture with plastic clay	Terrace, rice paddy
4	42.8	17.0-30.8	10.0-17.0	Noncalcic Brown	Variable	Terrace
5	46.3	29.3-38.4	18.5-30.4	Alluvial	Plastic clays and variable	Backswamps, river floodplains
6	36.3	14.0-30.4	7.9-14.0	Brown Alluvial	Silts to silty clay	River levees
7	31.9	15.7-26.8	8.2-15.4	Gray Podzolic	Sand over clays and variable	Terraces, undulating topography
8	34.0	14.3-30.8	5.4-14.2	Regosol	Sands	Uplands, dunes
9	47.0	29.1-43.3	23.6-28.5	Redish-Brown Latosol	Clays of low plasticity	Basalt plateaus with wide valleys
10	39.2	24.2-33.1	16.0-24.1	Grumusols, Red-Yellow Podzolic, Reddish-Brown and Red-Yellow Latosol, Lithosol	Variable over clay; clays of low plasticity, stony soils	Mountainous areas and plateaus, moderate to high relief

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13. ABSTRACT

Soil moisture, soil strength, and other relevant data were collected in Thailand during two wet seasons and one dry season for use in the development of methods to predict soil trafficability for off-road ground contact vehicles in Southeast Asia. Data were collected at 75 test sites distributed in eight geographic areas which had differences in soils, weather regimes, terrain, and land use.

From data collected monthly at the 75 sites, specific soil strength-moisture relations were derived to depict the changes in strength that corresponded to changes in moisture content. From data collected daily at 17 sites, specific soil moisture prediction relations were derived following procedures developed for sites in the United States. Results showed that the prediction methods were applicable to Thailand sites that were well drained. Modifications in the methods should be developed to account for the influence of water tables when present. Similarities in specific prediction relations between Thailand and the western hemisphere indicated that the development of average prediction relations is feasible.

Descriptions of Thailand and study areas are given in Appendix A. An application of the Thailand data, the derivation of a general soil moisture map for South Vietnam, is given in Appendix B. The basic data are summarized in Volume II.

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